Single-Sidebands in Communication Systems

A Bibliography

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SINGLE-SIDEBANDS IN COMMUNICATION SYSTEMS
A Bibliography
Compiled by Mildred Benton

September 1956

NAVAL RESEARCH LABORATORY
Washington, D.C.
CONTENTS

Preface
Abbreviations Used in Citations to Periodicals
BIBLIOGRAPHY
AUTHOR INDEX
SUBJECT INDEX
Preface

Utilization of the single-sideband method of transmission in communication systems was conceived in 1915. Early tests showed that advantages could be attained over the conventional double-sideband operation. Single-sideband, suppressed carrier transmission provides a means of obtaining economy of spectrum, savings in power and reduction of selective fading. Since 1915 considerable effort has been devoted to the study and evaluation of single-sideband characteristics and to the development of single-sideband techniques. Many technical and popular articles have been written on the subject, the earliest recorded in this bibliography being the classic one by Colpitts and Blackwell which appeared in the Transactions of the American Institute of Electrical Engineers during 1921.

Scope

This bibliography represents an attempt to record the classified and unclassified literature on the subject, including periodical articles, books and research reports. The period covered is 1921–July 1956. Some articles, with emphasis on high-frequency crystal units and crystal lattice filters, are cited, due to the fact that development in single-sideband tuning has depended on advances in the quartz crystal manufacturing art.

Arrangement

In order to make the majority of the literature references, which are unclassified, freely available, the bibliography is presented in two parts. Part I includes the unclassified references (492 items); and Part II (classified SECRET) includes the classified references (62 items). The latter part may be obtained through the usual channels utilized for procuring classified material.

References are listed chronologically by author; research reports by corporate authors, and periodicals and books by personal authors. An author index appears on pages 91 to 95; a subject index on pages 96 to 99.

For periodical references, the normal form of entry is author, title, and journal, volume, pagination, and date, followed by a brief annotation, or abstract quoted from an abstracting journal. Abbreviations for journal titles are based on those used by the Library of Congress. A list of these abbreviations together with the journals which they represent appears on the pages immediately following the Preface.

The form of entry for books is author, title, pagination, place of publication, publisher and year.
Research reports are recorded in a similar manner except that place of publication follows the corporate author. The report number is also included, following date of publication, as well as the contract number, for sake of convenience in ordering or borrowing; and the security classification.

The majority of references have been examined. When examination was not possible, due to non-availability of the periodicals, entries located in abstracting journals were used. Because of this fact, some foreign language articles are recorded in English rather than in the original language. In every such instance, however, a note indicates the language in which the article is written.

Sources Consulted

Bibliographic Index, 1937 - 1954.
Doctoral Dissertations Accepted by American Universities, 1950 - 1954.
Engineering Index, 1930 - 1955.
Industrial Arts Index, 1930 - July 1956.
Wireless Engineer, 1930 - June 1956.
and the Catalogs of the Technical Information Division, Library of Congress; the Bibliographic Research Section, Bureau of Aeronautics; and the Naval Research Laboratory.

Acknowledgment

Special thanks are due Mrs. Kathryn Kozak for assistance in finding material, and for preparing the author index and typing the bibliography.
Abbreviations Used in Citations to Periodicals

The following is a list of abbreviations used in citing references to periodicals, followed by the complete title of the periodical.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Title</th>
</tr>
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<tbody>
<tr>
<td>Alta Freq.</td>
<td>Alta Frequenza</td>
</tr>
<tr>
<td>Ann. Radioelec.</td>
<td>Annales de Radioelectricité</td>
</tr>
<tr>
<td>Arch. Elek. Ubertrag.</td>
<td>Archiv der Elektrischen Übertragung</td>
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<tr>
<td>Bell Lab. Record</td>
<td>Bell Laboratory Record</td>
</tr>
<tr>
<td>Bell Sys. Tech. J.</td>
<td>Bell System Technical Journal</td>
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<tr>
<td>Brown Boveri Rev.</td>
<td>Brown Boveri Review</td>
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<tr>
<td>Cables &amp; Transm.</td>
<td>Cables &amp; Transmission</td>
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<td>Communs.</td>
<td>Communications</td>
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<td>Communications Engineer</td>
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<td>Communications News</td>
</tr>
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<td>Dissertation Abstracts</td>
</tr>
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<td>Electrical Review</td>
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<td>Elec. World</td>
<td>Electrical World</td>
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<td>Electronic Eng.</td>
<td>Electronic Engineering</td>
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<td>Elektrotech. Z.</td>
<td>Elektrotechnische Zeitschrift</td>
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<td>Ericsson Rev.</td>
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<td>Fernmeldetechn. Z.</td>
<td>Fernmeldetechnische Zeitschrift</td>
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<td>Field Engrs. Electronics Dig.</td>
<td>Field Engineers Electronics Digest</td>
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<td>Franklin Inst. J.</td>
<td>Franklin Institute Journal</td>
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<td>Funk-Tech.</td>
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<td>Funktechnische Monatshefte</td>
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<td>Hochfrequutech. u. Elektroakust.</td>
<td>Hochfrequenztechnik u. Elektroakustik</td>
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iii
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<tr>
<th>Journal/Proceedings/Transactions</th>
<th>Translation</th>
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<tr>
<td>Inst. Radio Engrs. J. (Australia)</td>
<td>Institute of Radio Engineers (Australia). Journal</td>
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<tr>
<td>Izvest. Elektroprom. Slab. Toka.</td>
<td>Izvestia Elektropromishchnosti Slabovo Toka</td>
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<td>Marconi Rev.</td>
<td>Marconi Review</td>
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<td>Onde Elec.</td>
<td>Onde Electrique</td>
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<td>Philips Tech. Rev.</td>
<td>Philips Technical Review</td>
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<tr>
<td>Radio &amp; TV News</td>
<td>Radio &amp; Television News</td>
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<td>RCA Rev.</td>
<td>RCA Review</td>
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<td>Res. for Ind.</td>
<td>Research for Industry</td>
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<td>Sylvania Technol.</td>
<td>Sylvania Technologist</td>
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<td>TV Eng.</td>
<td>Television Engineering</td>
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<td>TV Soc. J.</td>
<td>Television Society. Journal</td>
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<tr>
<td>Teleph. verw.</td>
<td>Telefunken Zeitung</td>
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<td>Telefunken Ztg.</td>
<td>iv</td>
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Telegr. Fernspr. u. Funktech.
Telegr. u. Fernspr. Tech.
Tele-Tech & Electronic Inds.
Veröff. Nachrichtentechnik

Wireless Engr.
Wireless World & Radio Rev.

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v
SINGLE SIDEBANDS IN COMMUNICATION SYSTEMS

A Bibliography

1956


   Reports essential completion of planning phase; and engineering activity in design phase.

   Objective is an engineering investigation to develop single-sideband signal generator for use as laboratory equipment in testing and evaluating the performance of the receiving components of single-sideband radio communications systems.

   Single-sideband transmission is mentioned as one of the technical measures available to improve spectrum economy.

   In German.
   Translated title: Attachment for single-sideband reception.

   The electromechanical filter, employing a series of mechanically resonant elements mechanically coupled together, is of particular interest in the communications field because of the greatly increased use of single-sideband systems.
   This article is devoted to a general review and discussion of such filters.
   Discusses the design of a high-power linear amplifier intended for use as a power amplifier for single-sideband transmitters.


   The single-sideband exciter described used the Collins filter in a circuit arrangement combining practically all the operating features single-sideband experience has shown to be desirable.

   The transition problem; review of AM and single-sideband communication systems; equipment modifications for improved compatibility; and a sample transition procedure.

   Covers compatibility, single-sideband advantages, types, problems, feasible techniques, bi-mode operation and an explanation of terms used in connection with single sideband.

   Characteristics of the new HF receiver, the AN/ARC 58 which is expected to provide a 40-fold (16 db.) increase in effective power as compared with the double-sideband (DSB) sets now used for long-distance military and airline communications.

   Presents design philosophies and circuits to be used in proposed single-sideband equipment.

15. SAC TO INSTALL SIDEBAND SYSTEM ON BOMBERS. Army-Navy-Air Force Register 77:6, June 16, 1956.
Cites advantages in communications to be gained by use of single-sideband by Strategic Air Command.

As a result of development work, the armed services now have available four- and twelve-channel cable carrier systems that can operate together and can be used with companion radio relay links. The four-carrier channels use lower sideband transmission with the carrier suppressed.

The purpose of this paper is to examine the relative merit of amplitude modulation (AM) and single-sideband (SSB) communications systems with special attention to airborne applications.

Except on 25 mc, the tone frequencies of 440 and 600 cps from WWV are being operated experimentally as single-upper-sideband with full carrier. Power output from the single sideband transmitter is about a third the carrier power.

1955

Ch. 12: Single sideband.
This handbook is revised and re-issued at frequent intervals.

In German.
"Describes equipment conforming to the usual restriction of transmitted power to 10 W and bandwidth to 30-375 kc/s. Each channel requires a bandwidth of 2.5 kc/s and the equipment is designed to
provide up to 18 both-way channels. Terminal equipment and intermediate amplifier bays are described and illustrated." Sci.Abs. 58 B:2698, 1955.


Carrier links over high-voltage lines can be operated on amplitude or frequency modulation. The various methods of modulation used (single- and double-sideband and frequency modulation) possess quite different operational characteristics, which the author compares in the present article, devoting particular attention to the investigation of susceptibility to noise, distortion and cross-talk attenuation.


Measurements show that Brown Boveri single-sideband sets with adjacent transmission and reception bands in the same two-way channel can keep within the same limits (particularly in respect to cross-talk) as are considered appropriate for channels with a much greater frequency difference (at least 8 kc/s).


In the section on power system communication equipment it is stated that "the introduction of the single-sideband unit with a 100 W output stage represents a milestone along the Brown Boveri road of constructional development," p. 71-72.


It is intended to point out the advantages of employing this method of communication and indicate the relative simplicity with which it may be accomplished.


Summary article with same title in IRE Proc. 41:413,1953.

A description of the design of transmitter similar to that mentioned in the author's book in Single Sideband Techniques but with a little more power output and using a toroid filter for sideband selection.

   Use of r-f feedback in two-stage tetrode power amplifier provides high power gain with low distortion in single-sideband transmitters where generation of noise in adjacent speech channels must be avoided.

    SSB AMATEUR EQUIPMENT. 15p., illus., 1955.
    General description and specifications for receiver, transmitter, optional equipment combinations and accessories.

    (Interim Letter Rpt. IDR-395-1) (Contract AF30(635)-4504)
    Reports on engineering plans, orientation for project and design.

    Presents the proposed plan of attack for the Air Force Single-sideband program. Goes into considerable detail both in system arrangement and in the circuits used for the individual functions.


    SINGLE SIDEBAND. 19p., illus., 1955. (Application B. 9)
    Ratings and selection of tubes for single sideband; amplifier design and operation; adjustment and monitoring; single-sideband data.

    Engineering details on commercially available single-sideband equipment.
33. General Electric Co. Heavy Military Electronic Department, Syracuse, N. Y.
   BETTER COMMUNICATIONS WITH SYNCHRONOUS DETECTION, by J. P. Costas. 24p., diags., June 1955. (RNA-7562)
   Single-sideband reception is mentioned in this discussion of synchronous detection and theory of operation of the synchronous detection receiver and the suppressed-carrier transmitter.

   Describes the adapter which utilizes the basic McLaughlin principle with the addition of a few useful operating features explained by the writer.

   The writer directs attention to the fact that more attention is being paid to the reception of single-sideband phone signals.


   In German.
   Translated title: Possibilities of equalization in vestigial sideband transmission of television.
   Outlines a method of measuring the attenuation and group-delay characteristics of vestigial sideband filters and presents results obtained on 3 transmitter filters and on 3 receivers, together with video output oscillograms obtained with 500 kc/s square-wave video inputs of several amplitudes.

   The article discusses certain aspects of the theory, tuning, dimensions, and application of the various types of trap produced by Brown Boveri.
   The type of trap suitable for use with two parallel single-sideband links is suggested on p. 308.
   A system is described in which a single control in one phase branch of the modulating circuit is used to maintain the amount of sideband suppression constant when the output frequency is varied.

   The description of the power spectrum computer of the Naval Research Laboratory, Radio III, includes the statement that the input is single-sideband amplitude-modulated magnetic tape.

41. Holahan, James.  SSB DESIGNED FOR AIR-GROUND COMMUNICATIONS.  MORE VOICE CHANNELS PER METER, MORE TALKING POWER PER WATT.  Aviation Age 24:40-51, illus., 1955.
   Recent advances have made single-sideband systems practical, according to the Electronics Editor of Aviation Age, who reports his findings at Collins Radio Co., Cedar Rapids, Iowa.

   Abstract states that the transient speed response of two-phase servo motors of conventional squirrel-cage design is investigated for operating conditions in which the control phase is energized with a suppressed-carrier signal and the reference phase with a 90-degree-shifted carrier signal.


   Suggests steps for suppressing single-sideband distortion in television (monochrome or color).

Describes a single-sideband high-frequency telephone system for simplex or duplex operation. It is usable for telephony, manual telegraphy and teleprinter operation over short and medium distances, and is adapted for use by nontechnical personnel for many of the simpler telecommunication requirements around the world.

   Bibliography, p. 742-743.
   This paper is intended to serve as an introduction to the many references quoted. Mention is made of single-sideband system in connection with modulation and multiplexing.

   Announces award of contract to RCA for study expected to result in recommendations as to technical concepts and circuitry necessary to introduce single-sideband communication into HF military applications.

   Details of system for electronic control of bandwidth in selectable single-sideband dual diversity receiver.

49. Massachusetts Institute of Technology. Lincoln Laboratory, Cambridge, Mass.
   In the section on modulation techniques, there is a comparison of some of the methods of modulating a UHF wave with a multiplex signal. Single sideband is discussed on p.18, indicating that it has several attractive advantages over FM and forecasting that "the future will see the development and application of single-sideband equipment in long-range UHF radio systems."


INSTRUCTION BOOK FOR SINGLE-SIDEBAND CONVERTER CV-216/URR. 71p., illus., Mar. 25, 1955. (NAVSHIPS 92456) (Contract NObsr-52642)


Cites advantages offered by single-sideband transmission and reception for greater efficiency and safety.


Outlines the structure of the communications network and the tasks which must be carried out. It is stated that all of these tasks are performed by carrier current channels operating on the single-sideband system, by which double-sideband channels are being gradually replaced.


An analysis and assessment of carrier equipment, using double- and single-sideband modulation.

56. Radio Corporation of America, Rocky Point, N. Y.


The purpose of this report is to present the results of tests that have been made to evaluate the performance of the non-linear type of single-sideband transmitters.

57. Radio Corporation of America. RCA Laboratories Division. Industry Service Laboratory, Long Island City, N. Y.

ELECTROMECHANICAL FILTERS FOR 100 KC CARRIER AND SIDE-BAND SELECTION. 10p., illus., June 2, 1955. (LB-981)
The electromechanical filter, employing a series of mechanically resonant elements mechanically coupled together, is of particular interest in the communications field because of the greatly increased use of single-sideband systems.

This bulletin presents both a general discussion of a torsional type mechanical filter and its termination by mechanical and electrical means, and a detailed description of two 100-kc filters, one 50 cycles wide and the other 3.1 kc wide.

A quick look at single-sideband fundamentals.


Suggests that a simple means of obtaining maximum output signal is to use two audio tones of equal amplitude to modulate the single-sideband transmitter.

1954

Material digested from technical articles appearing in CQ and QST. Both the filter method and the balanced modulator method of generating single-sideband signals are described.

Problems associated with single-sideband transmission are reconsidered for aircraft application, with special regard for restrictions in size and power of equipment; circuit techniques developed for aircraft set are also applied to associated ground equipment, which is often required to be light and mobile.

Single-sideband carrier system with carriers spaced at 6 kc intervals.
   In French. English summary, p.954.
   Translated title: Vestigial sideband television transmission systems.

   Information about single-sideband installations and an illustration of 18 single-sideband power line carrier equipments, p.71-72.

   Example of typical frequency division multiplex equipment by Lenkurt, which will provide up to 24 toll quality voice channels using single-sideband suppressed carrier methods.

   In French.
   "Pt. II describes the special features of the transmitter-receiver Type TH861 A and B, designed for telephony and telegraphy between two fixed or mobile stations whose distance apart may be a few hundred km. The frequency coverage is 3-12 Mc/s, the operating frequency being derived from a quartz crystal. Frequency changing is effected in<1 min. by means of plug-in circuit units. Peak power to the feeder is 10W, the pass-band at 6 db is 300-3000 c/s and the attenuation of the sideband not used is at least 40 db. The processes in the transmitter are reversed in the receiver, the same quartz crystals being used. Synchronization between two TH861 sets is effected by an arrangement permitting slight adjustment of the local frequency used in reception. Such adjustment remains effective over long periods." Sci.Abs. 58B:3442., 1955.

   In Italian.
   Translated title: Study of balanced modulator with tubes for single-sideband radio communication.

   The author has brought together, under one cover, information on single sideband. Material in the first five chapters is an edited and
rewritten version of the six-part series, "Getting Started on Single Sideband" that was published in CQ Magazine during 1953.

See Item 106 for articles.


Designing lattice and half-lattice crystal filters.


"Pt. III describes in greater detail the Type TH863 transmitter, which has a peak power of ∼50W, amplifier Type TH911, with a peak power of ∼400W and the Type TH864 receiver. The TH863 transmitter covers the range 2.5-15 Mc/s in 4 overlapping ranges, each sub-range having its own plug-in circuit. The TH911 amplifier is designed to be driven by the TH863 transmitter, thus increasing its output power. The TH864 receiver covers the same total frequency range as the TH863 transmitter and has identical sub-ranges, with corresponding plug-in circuits." Sci.Abs. 58E: 3442, 1955.


This paper describes an electronic single-sideband modulator for shifting the carrier frequency of a microwave signal by a fixed amount. The device is one of the first practical applications of the double-refraction properties of ferrites with transverse magnetic fields.


"Accepting the premise that the limits of existing primary group and super-group bands should be observed, arguments are put forward in favor of a single-sideband suppressed-carrier system having a primary group of 8 channels with carriers spaced 6 kc/s apart instead of the conventional primary group of 12 channels with carriers spaced 4 kc/s apart." Sci.Abs. 59B:823, Feb.1956.

- 12 -
   In French.
   "Pt. I discusses the particular difficulties of producing relatively cheap low-power communications equipment and shows how the desired result has been achieved by limiting the number of telephony channels to only one and avoiding the use of a.f.c. in the receiver, in which the demodulation of the received wave is effected by means of a stable signal of large amplitude, produced locally." Sci.Abs. 58B:3442, 1955.

   In German.


   Cites several improvements for operating convenience added to the 10B Multiphase Exciter.


   Whether or not to drive a tetrode linear into grid current is a question that can be argued both ways. This article outlines some of the factors favorable to Class AB operation and describes an amplifier that embodies the ideas under discussion.


   Compares amplitude modulation and single sideband.

In a series of flight trials over ranges up to 2000n. miles, 80% of the S. S. B. transmissions were satisfactory against 30% in the case of D. S. B.


Improvements in diversity reception and multiplexing equipment provide increased communications traffic handling facilities in existing circuits used by military.


Single-sideband transmitter for world-wide service having remote control and four speech channels and operating in band 4 to 27.5 mc with 30 lw peak envelope power.


Of interest to the builder of a crystal-filter single-sideband exciter.

AN ELECTROMECHANICAL SHIFTER FOR RADIO FREQUENCIES, by R. A. McFarlane. 3p., diags., May 1954. (ERB318) (NRC 3315)

Describes the goniometer method of producing the single-sideband signal.


Translated title: Use of negative feedback in independent sidebands and double-sideband transmitters.

"The author first briefly reviews the general principles of independent sidebands transmission. He then studies the various causes of distortions and cross-talk in a transmitter used for transmitting two independent sidebands of two coherent bands. Having examined the use of negative feedback to reduce these distortions, the author describes a special device used on 2 kW and 20 kW S.F.R. transmitters and studies a phase-correcting network designed for a transmitter operating range between 375 and 28 Mc/s.

"The results obtained guarantee a cross-talk of less than 35 db for a peak power of 20 kW in independent sidebands transmission and a distortion of less than 35 db in A3 double sideband transmission for an 80% modulation depth and a carrier power of 500 kW (U. D. C.; 621. 396. 4)."


In Czechoslovakian.

"The receiver described is an integral part of a unit which comprises: (1) a transmitter, (2) d.c. power supplies operating from 220 V mains, (3) filters, (4) a telephone set, (5) a measuring equipment, and (6) a line-finding equipment consisting of relays. The system employs double amplitude modulation; the first carrier frequency is $F_1 = 7.2$ kc/s, the upper sideband being totally and the carrier partially suppressed; the second carrier $F_2$ lies between 40 and 300 kc/s, one of the sidebands and the carrier being suppressed. Each channel employs a band-width of 2.5 kc/s, the cross-talk attenuation between adjacent channels being 3N. The receiver has a sensitivity of 15 mV (on 110 kV lines), an input impedance of 120Ω, output impedance of 600Ω, non-linear distortion of < 5% and an audio bandwidth extending from 300 c/s to 2.1 kc/s. The first carrier $F_1$
is employed to actuate an automatic gain control circuit in the receiver. Design of the receiver is discussed in detail and its performance is illustrated by a number of graphs and curves." Sci.Abs.58B: 1286, 1955.


A general review of the evolution of air-ground communications; the present DSB system; brief history of single-sideband radiotelephone communication; capabilities and status of development of single sidebands; design considerations of a single-sideband system; problems of conversion from double sidebands to single sidebands; single-side system equipment considerations; economic factors involved in a conversion of the present double-sideband system to a single-sideband system; present status of single-sideband development.


Demodulation of single-sideband signals, p. 365-366.


Translated title: Siemens single-sideband receiver KW2/6.
"A detailed description of the Siemens receivers for the reception of 2.5 - 20 Mc/s and 4 - 28 Mc/s channels is given. They handle input signals from 0.2 to 20,000μV and have a noise factor of 6 db. The receiver has a 2-valve r.f. amplifier with 3 tuned circuits and is of the double superhetrondyna type, the intermediate frequencies are 2112 kc/s and 112 kc/s. The attenuation of the adjacent channel is >70 db, cross-modulation suppression 55 db. The automatic frequency control is of particular interest; a special crystal filter selects the pilot carrier, radiated by the transmitter, and uses it for the demodulator of the receiver and the operation of a.f.c. The a.f.c. control voltage is derived by phase comparison by means of a further crystal filter and is fed to a d.c. motor which readjusts the tuning inductance of the first oscillator." Sci.Abs. 58B: 1332, 1955.


   Design and performance of independent sideband transmitter providing peak power output of up to 70 kw in range 4-22 Mc; although primarily intended for independent sideband operation using 2-channel drive, it can also be used for double-sideband telephony and CW and MCW telegraphy.


   The phase-rotation method of generating a single-sideband amplitude-modulated signal requires the use of 90-degree phase-difference networks covering the audio frequency band. The purpose here is to present a design procedure for obtaining these networks and to discuss some of the practical matters which arise in their construction and alignment.


   Details of television monitor which employs superheterodyne receiver with i-f bandshaping circuits to give vestigial-sideband characteristic.


The theory underlying vestigial sideband transmission is reviewed, and a comparison made of tolerances to noise and transmission distortion of double-sideband PCM systems employing two pulse amplitudes.


Single sideband, p. 169-175.


See Item 68 for book utilizing same material.


The application of exalted carrier and single-sideband methods in a triple diversity system is illustrated.


The author contends that transoceanic communication can be accomplished dependably with single-sideband diversity equipment.


Describes the single-sideband converter developed for the U.S. Army Signal Corps by Hoffman Laboratories, Inc. The new unit
makes possible multichannel teletype or facsimile operation with voice transmission on single LF, MF or HF carrier.

A low-power Class B linear for one of the new simplified single-sideband exciters.

A suggestion for selectable-sideband reception without double conversion.

Description of an i.d. amplifier designed to handle c.w., a.m. and single-sideband signals, utilizing the maximum usable selectivity in each case.

Use in single-sideband transmitting techniques.

A mixer is described which has an inherent output of only the sum or only the difference of the two input frequencies. An explanation of the principle is given and details of a model for mixing 208 Mc/s with 0-2 kc/s.

Object of the study: to design, develop, and produce a single-sideband converter.

Report on findings that single sideband is better suited for long-range paths and is less likely to fade than conventional AM systems.


"The design, construction and performance are described of a receiver suitable for long-distance links operating in the range 4-30 Mc/s, and designed for reception of the type of signal described in part 2 (2175 of July (Owen & Ewen)). Response is uniform to within 2 db from 100 c/s to 6 kc/s. The receiver closely approaches the limits of performance theoretically obtainable in respect to sensitivity, faithful reproduction, and freedom from avoidable interference." Wireless Eng. 30:2425, 1953.


Summary only.


In German.


"Pt. I draws direct comparison between single-sideband suppressed carrier (s.s.s.c.) and double-sideband a.m. transmission from both theoretical and practical standpoints. It is shown that for the same amount of available power, the power output with s.s.s.c. is 8-10 x that of conventional a.m. Two methods of generating s.s.s.c. namely the filter and phase-shift methods are described and details are given of interference problems. Pt. II deals with the practical design of a 600 W output s.s.s.c. transmitter. Details are given of the active audio phase-shift network, balanced modulators, frequency converters and the power amplifier. Block and circuit diagrams, filter and phase characteristics and photos are given." Sci. Abst. 57B; 761, 1954.

- 20 -
121. Naval Air Test Center, Patuxent River, Maryland.

EVALUATION OF SINGLE SIDEBAND COMMUNICATION SYSTEM.
Final Report. 44p., Nov. 20, 1953. (Rpt. 1)

Point-to-point tests were made using the Western Electric LE system single-sideband communicating equipment. The LE single-sideband receiver and the AN/ARR-15 double-sideband receiver were compared during long-range flights in which both were receiving the same double-sideband signal.

The single-sideband receiver proved greatly superior to the double-sideband receiver during test periods.

122. Owen, F. C. and Ewen, A. B. SINGLE-SIDEBAND MULTI-CHANNEL OPERATION OF SHORT-WAVE POINT-TO-POINT RADIO-LINKS.

"The present equipment is an improved form of that previously described (2395 of 1948 (Bray et al.)). It generates a low-power independent sideband signal comprising two 6-kc/s channels, one on each side of a reduced-level 3.1-Mc/s pilot carrier, suitable for application to the final modulator and power-amplifier stages of a s.w. transmitter. Alternatively a single-channel double-sideband signal can be generated. The associated monitor receiver is designed to accept signals from the transmitter drive unit at 3.1 Mc/s or from the power-amplifier stages at radiation frequency." Wireless Eng. 30:2175, 1953.


Multichannel single- and double-sideband transmissions using carrier frequencies in the range 30-450 kc are considered from the power efficiency point of view.


When used in place of the AM transmitter, the SSB Mobile features automatic receiver reinsertion on single-sideband reception, carrier reinsertion in transmitter to enable the "uninitiated" to copy on AM, and crystal control rubbering of approximately five kilocycles.

125. RADIO EQUIPMENT FOR PAKISTAN. Electronic Eng. 25:197, 1953.

Included in the equipment being sent to Pakistan by the Australian
Government in accordance with the Colombo Plan, are 17 single-sideband receivers.


The mechanical filter shows promise for use in many applications, including the simplification of single-sideband transmitter circuits.


Describes an i.f. filter for 'phone signals.


129. Skwirzynski, J. K. RESPONSE OF A VESTIGIAL SIDEBAND SYSTEM TO A "SINE-SQUARED" STEP TRANSITION. Marconi Rev. 16: 8–24, 1953.


The proposal that "automatic" carrier exaltation could be provided by a number of paralleled narrow-band, adjacent filter channels with each channel arranged so as to transmit only signals stronger than a certain level, has been investigated in part.

Design of a laboratory model to illustrate this proposal is discussed.


Progress is reported in the investigation of negative-reactance phase shifters for the purpose of cancelling phase distortion and delay in 90° wide-band audio phase shifters of the type used in single-sideband systems.

132. Stanford University. Electronics Research Laboratory, Stanford, Calif. COMMUNICATION TECHNIQUES (MODULATION) PROJECT. 7p.,
Work on the multiple-tuned circuit "automatic" carrier exaltation system for single-sideband reception has been brought to a close with completion of a 9-channel assembly. Preliminary tests of transmission versus frequency, and of the volume-expansion action, have been satisfactory.


Research during the period included automatic detection of single-sideband signals.

There is also presented in this report a listing of all technical reports, publications and patent disclosures prepared under, or in connection with, the project since its inception.


A polyphase selective system suitable for single-sideband transmission or reception is described, in which the selective action takes place directly at radio frequency in such a way that a number of individual systems may be cascaded in situations where a very high degree of overall selectivity must be obtained.

135. Wright, Howard. LOW-PRESSURE MODULATION FACTS. DOWN-TO-EARTH TALK ABOUT RADIO TELEPHONY. QST 37:15-17, 110, illus., Jly. 1953.

Single-sideband techniques.

1952


Special features and performance data.

The "series" balanced modulator for single-sideband work is presented because of its simplicity, good linearity, and excellent carrier suppression.


"The article outlines the principles of single-sideband working, its advantages, and describes the basic techniques used for the transmission of multi-channel telephony and telegraphy." Sci.Abs. 56B: 752, 1953.


Bibliography, p.119-123.

In connection with the problem of obtaining the selectivity needed in single-sideband reception, the author has worked out a new system called the "diode mixer method radio-frequency selectivity." It is a phase-rotation method, with the particular feature that the desired selectivity is obtained at the radio-frequency level. In order to achieve this result, two main steps are taken which are believed not to have been used before. One of them is the frequency discrimination effect of the diode mixer. The other is the development of what are called "radiofrequency constant phase-difference networks."

The present work is concerned mainly with the theoretical aspects of the method.


Summary only.


An experiment with dual single-sideband reception.


Describes two carrier systems, type O and type N. An important difference is said to be the use of single sideband in the O rather than the double sideband in the N.


Advantages of applying single-sideband techniques to long-range aircraft communications on H. F. are discussed and related to the operating conditions of an airborne equipment.


The system described eliminates the need for costly linear r. f. amplifiers in the transmitter. The ph. m. component of the single-sideband signal is amplified by means of class-C amplifiers, while the a. f. envelope is separately detected, amplified and recombined with the r. f. signal at final stage. Experiments indicate that the performance of the system is equal to or better than that of the conventional transmitter with linear r. f. amplifier.

The transmitters considered are of the type using filters to suppress the unwanted sidebands. Factors discussed include balance requirements, frequency stability, choice of i.f. and methods of avoiding transmission of spurious signals.


Description of a transmitter designed for transoceanic communications and operating over the frequency band 4-23 Mc/s; four telephone channels are available. The main feature is the use of a servo-system permitting push-button tuning to any one of ten preselected operating frequencies in about 15 sec.


Tips on drift prevention for single-sideband signals.


Design requirements for h.f. amplifiers with low interchannel modulation and adjacent-band radiation are discussed.


In German.


In German.


Theory of operation and fundamental circuit design of an adapter for exalted-carrier single sideband communication reception.
158. Naval Research Laboratory, Washington, D.C.


Comparison of a Navy Ar-88 receiver modified for single-sideband reception with other receivers designed specifically for such operation indicated that a satisfactory single-sideband receiver can be produced by adding a special adapter to a standard general-purpose receiver.

159. Oswald, J. TOTAL OR PARTIAL SUPPRESSION OF A MODULATION SIDE BAND. Cables & Trans. 6:165-173, Apr. 1952.

"Analysis of the characteristics of the envelope of an a.m. signal when the carrier wave and one sideband are suppressed. A definition is given of the mean and the maximum degree of modulation of a stationary aleatory signal with limited spectrum and Gaussian distribution. Passage of a modulated wave through a filter is considered, the theory showing the existence of the two components in quadrature which characterize the response of an arbitrary linear network to a modulated signal. The probability law of the signal envelope and the degree of modulation are slightly modified by the suppression of a sideband, so that a compression of the envelope levels results. The theory is applied to vestigial-sideband transmission of a television signal." Wireless Eng. 29:173, Aug. 1952.


Bell Telephone Sys. Monograph 2055.

The system described operates in the frequency range 4-23 mc and provides four channels. Peak power output of the transmitter is 4 kw. Improvements with respect to earlier equipment include pushbutton selection of any of 10 preselected frequencies, use of varistors as modulators, a device to ensure full use of output whatever the number of channels in use, and reduction of out-of-band radiation and interchannel cross-talk. The companion receiver is described briefly.

161. Signal Corps Engineering Laboratory, Fort Monmouth, N.J.


It is the purpose of this report to describe the operation of the modified equipment and to present data obtained in an experimental evaluation of the equipment, at Coles Signal Laboratory.
The conclusion stated that the power amplifier BC-340 is useful as a linear single-sideband amplifier and is capable of delivering approximately 10 kilowatts of peak envelope power throughout the frequency range of the D-156000 transmitter.

162. Stanford Research Institute, Stanford, Calif.
(Contract DA36-039-sc-78)

As part of the investigation a radio transmitter has been constructed which generates a single-sideband signal in the frequency range of 1.5 to 3.0 mc and incorporates completely automatic tuning of all circuits.

This report includes a complete description of the transmitter and its performance as well as instructions for its operation. A section is devoted to the principle theoretical problems pertinent to the design of the high-level single-sideband transmitter. Another section presents the recommendations of the engineers concerning the present shortcomings of the equipment and future improvements that can be made.

163. Stanford University. Electronics Research Laboratory, Stanford, Calif.
COMMUNICATION TECHNIQUES (MODULATION) PROJECT. 6p., 1952. (Quart. Prog. Rpt. 11) (Contract W28-099-ac-131)

The voltage-controlled phase shifter designed to reduce the high losses in a single-sideband autocorrelation detector was completed. A method for producing automatic exaltation of a reduced carrier received by a receiver is outlined.

164. Stanford University. Electronics Research Laboratory, Stanford, Calif.
COMMUNICATION TECHNIQUES (MODULATION) PROJECT. 1lp., illus., 1952. (Quart. Prog. Rpt. 12) (Contract W28-099-ac-131)

Work on the multiple-circuit automatic carrier-exalting system for single-sideband reception resulted in the development of a simple and economical automatic volume expander circuit using rectifying crystals.

165. Stanford University. Electronics Research Laboratory, Stanford, Calif.
COMMUNICATION TECHNIQUES (MODULATION) PROJECT, by O. G. Villard, Jr. 7p., illus., 1952. (Quart. Prog. Rpt. 13) (Contract W28-099-ac-131)

-28-
Investigation was continued of negative-reactance phase shifters for cancelling phase distortion and delay in 90° wide-band AF phase shifters of the type used in single-sideband systems.


A method of connecting 90-degree audio phase-difference networks for use in selective-sideband transmission and reception is shown, whereby an overall performance is obtained which is analogous to the cascade operation of conventional filters.


Mentions the normal amplifier gain versus frequency characteristic with a sharp peak superimposed on top. Such a characteristic is useful for exalted-carrier reception of a.m. signals, or for reception of reduced-carrier single-sideband transmissions.


An account of measurements of noise voltages on a multichannel single-sideband suppressed-carrier system.


Practical pointers on two methods of operation.
172. Bloch, H. SINGLE-SIDEBAND EQUIPMENT AND HIGH-SPEED CYCLIC
TELEMETRY FOR CARRIER-CURRENT OPERATION ON HIGH VOLTAGE LINES. Tech. Mitt. Schweiz. Telegr.-Teleph. Verw. 29:298-305,
Aug. 1, 1951.
   In French and in German.
   Description of Brown Boveri equipment exhibited at the 1951 Swiss
Fair in Basle.

460-464, figs., Nov. 1951.
   To absorb the power of the unwanted sideband, a 5-kW liquid-cooled resistor having an incorporated power indicator has been supplied.

ENGINEERING INVESTIGATION OF METHODS AND EQUIPMENTS
FOR RECEIPTION OF SINGLE-SIDEBAND SIGNALS. Final Report,
16 July 1950 - 9 February 1951. 49p., charts, Feb. 9, 1951. (Contract
W36-049-sc-38263)
   An engineering investigation to evaluate the merits of certain
methods of reception of single-sideband signals and construction and
delivery of experimental models of single-sideband receiver converters.

175. Goodman, Byron. A TWO-STAGE LINEAR R. F. AMPLIFIER. MORE

176. Grammer, George. D. S. R. C. RADIOTELEPHONY. QST 35:11-16,
May 1951.
   The type of phone transmission described in this article offers a
very marked increase in sideband power output over amplitude modula-
tion of the well-known type.

4-CHANNEL SINGLE-SIDEBAND HIGH-FREQUENCY RADIO-TELE-

100 kc/s. NARROW BANDSTOP CRYSTAL FILTER FOR A SINGLE-
9p., Apr. 9, 1951. (Radio Rpt. 2064) (CRB ref. 51/1626)
Details are given of the design and performance of a narrow-band rejection filter for the suppression of a 100-kc carrier frequency. A quartz-crystal filter is employed, with 2 identical bridged-T sections, each of which has one crystal resonator in the shunt arm. The filter is hermetically sealed. The general form of construction is like that of other filters designed for single-sideband equipment. Satisfactory performance was achieved with the sample filters constructed.


A phase-modulator keyer-adapter has been designed to operate in conjunction with conventional CW transmitters that are equipped for frequency-shift keying. This adapter covers the frequency range 2 to 5 megacycles, delivers 5 watts RF power output to a 50-ohm load, introduces no frequency instability or frequency drift, and can be easily and accurately tuned and adjusted entirely by meter without the use of other instruments. It was designed, produced, and tested by NRL as one element of a multiple-tone transmission system utilizing single-sideband reception of phase-modulated transmissions.

Severe frequency stability requirements result in poor unwanted sideband rejection, making the AN/FRT-7 unsuitable for Navy use. Outphasing method of single-sideband generation and reception is feasible.

Attributes popularity of single-sideband operation to use of voice-controlled break-in, and describes the system in use at WIFAJ that permits loud-speaker with voice-controlled break-in.


"Description, with block diagram, of a receiver for the range 4-23Mc/s which has an unbalanced 75Ω input and is capable of receiving single-sideband signals with carrier as much as 20 db below one of two equal tones which completely load the transmitting equipment. Special features of the receiver are the choice of either a variable-frequency oscillator or a crystal-controlled oscillator for the first beating oscillator, limiters for reconditioning the received carrier, a.f.c. circuit with very few adjustments, a squelch circuit which prevents operation of the a.f.c. circuit during deep fading, a common main amplifier for both sidebands and carrier, and selectivity and a.g.c. that results in minimum cross-modulation and maintains maximum signal/noise ratio. Stabilized power-supply units are fed from 115V, 50-60 c/s mains and take 500 W."

Sci. Abs. 54B: 3120, 1951.


Describes a new multi-channel single-sideband radio transmitter.

188. SINGLE-SIDEBAND COMMUNICATION.  Res. for Ind. 3:4-6, Sept. 1951.


Each of the advantages of single-sideband operation as well as the problems it presents are discussed fully.
A laboratory single-sideband signal generator for general purpose use has been completed.

The possibility of detecting reduced-carrier single-sideband signals by autocorrelation techniques is investigated in the hope of finding a means for automatically exalting a reduced carrier with minimum delay at any frequency within a certain band of uncertainty.

Conventional approaches to the development of a detection system for simplifying the tuning of single-sideband transmissions are reviewed. One system involves simultaneous AM and FM detection for demodulation of carrier-less single-sideband voice signals.

Publications resulting from the development work are listed with author's name and completion date. Debugging of experimental apparatus for examining proposed autocorrelation detector is in progress. Experiments near 1000 c. in an investigation of the parallel carrier-selecting filter system showed that Q's of the order of 200 are obtainable with simple steel-bar assemblies, but mechanical problems existed at higher frequencies because of the rapid decrease in Q and vibration amplitude. Attempts are being made to extend the operating frequency of the tunable selective amplifier to the RF range by combining the IF shunt version with a crystal-controlled converter.

A cancellation method is described for obtaining single-sideband
selectivity which utilized RF phase-difference networks (analogous to AF phase-difference networks) in conjunction with a diode detector in which the input impedance to the RF source is a function of the impedance on the AF side. A preliminary model of the system appeared feasible. The amount of distortion introduced by the diode detector is to be determined.


A simple electronic attachment for communication receivers is shown, which performs many of the functions of the conventional intermediate-frequency quartz crystal filter. The attachment may be connected without modifying the receiver in any way, and several may be added to a given receiver if desired.

It is possible with this attachment to obtain the normal receiver response characteristic with a sharp peak (perhaps two or three hundred cycles wide) superimposed on top. This composite characteristic is useful in the reception of reduced-carrier double- and single-sideband transmissions. The height of the peak -- and consequently the degree of carrier exaltation obtainable -- is readily adjustable.


Gives current status of work on various phases of the project.


Developmental work on high-quality single-sideband system design was concerned with correcting the phase-frequency distortion inherent in conventional constant-phase-difference networks. The theoretical treatment was generally limited to single-sideband receivers employing the constant-phase-difference network principle of sideband rejection. A compact design theory which simultaneously provides
linear through phase and constant phase difference was not achieved. Such networks are possible, but the procedure is tedious and involves trial and error. The important specific results of the investigation were an improved theory of standard constant-phase-difference networks (with incidental filter applications), and an analysis of methods for obtaining phase equalization.


The monthly reports of the work done under this contract have discussed the weakness of the standard type of constant-phase-difference network, as applied to single-sideband systems. They have inherently non-linear phase-frequency characteristics when considered as transmission networks alone. This makes them unsuitable for the transmission of waveshapes which must be preserved, although they are excellent for speech systems and others which are concerned only with the steady-state behavior. The study reported on here undertook to modify the standard design method to provide not only the sideband rejection feature, but also to provide good waveshape or "transient" transmission.


Several single-sideband systems using constant-phase-difference networks are compared from the standpoint of their waveform transmission properties.


Summary only.


It is the object of the invention to provide a single-sideband signal generator which does not require the use of a radio frequency phase shifting network or other phase shifting network requiring adjustment each time the frequency of operation is changed.

Detailed description of a single-sideband transmitter using a typical lattice.


"Discussion with reference to the type of transmitter described by Villard (893 of 1949). The two balanced modulators are driven by r.f. voltages in quadrature. A.f. modulating voltages, also in quadrature, are applied in push-pull to the valve grids of each modulator. The anode-current pulses of all the four Eimac Type 4-250A valves used develop power in a common anode tank circuit. When properly operated, only one sideband is present in the output. Details of the alignment procedure are given, and a specially developed alignment indicator is described which consists essentially of a single-frequency test source of four quadrature a.f. modulating voltages and four gated phase-sensitive detectors, each one of which is assigned to the examination of one particular component in the detected output of the transmitter." *Wireless Engr.* 30:2481, 1953.


Treats the subject in a simple and general manner. Brings together information from various sources.

1950


Sidebands, p. 413.


"Deals with various a.f.c. systems as applied in single-sideband receivers. A brief explanation is given of the fundamental operations of single-sideband receiver and transmitter, and the
various elements of an a.f.c. circuit are discussed in detail, namely, the pilot filter, the amplitude limiter, the discriminator and the means for correcting the frequency of the local oscillator. Two forms of a.f.c. circuit can be distinguished, namely, the electronic system and the electromechanical system. When fading occurs, a combination of both systems is required for single-sideband reception. Special attention is paid to the mechanical a.f.c. system for which a 'flotor' has been designed. This is a small variable condenser of a special form in which fluid damping is applied. Further, attention is given to the phase relations in the a.f.c. circuit with regard to frequency variations. Special problems arising when a.f.c. is used in conjunction with frequency-shift telegraphy are briefly mentioned. An entirely electromechanical a.f.c. system which synchronizes on the 'off' frequency seems to be the best solution for this type of transmission." Sci.Abs. 54B:2854, 1951.


MS thesis, University of Illinois.

The paper attempts to furnish complete up-to-date information on single-sideband suppressed carrier as well as giving the results of experiments conducted by the author. It includes a theoretical study, a description of equipment now being used, a review of results obtained by the amateurs, a report on experiments conducted to establish a minimum requirement for equipment, and a discussion of possible new techniques.


Uses the unit described by Goodman in his article "The Basic Phone Exciter" as the basis for a more compact design suitable for the foundation of a kilowatt all-purpose transmitter.


The unit described forms the basic part of a single-sideband transmitter.
212. Crosby Laboratories, Mineola, N. Y.
Single-sideband system considerations, p. 34-37.
Modulated wave amplifier - a new system for the amplification of single-sideband signals.

213. Crosby Laboratories, Mineola, N. Y.
ENGINEERING INVESTIGATIONS OF METHODS AND EQUIPMENTS FOR RECEPTION OF SINGLE-SIDEBAND SIGNALS, by M. G. Crosby. 47 p., illus., Jan. 16, 1950. (Quart. Rpt. 3) (Contract W36-039-sc-38263)
Progress on the investigation of the various functions of the single-sideband receiver resulted in the development of an improved all-electronic automatic-frequency-control system which appears to have all of the advantages of the motor-operated systems, but is simpler, easier to tune, and more flexible.

214. Crosby Laboratories, Mineola, N. Y.
ENGINEERING INVESTIGATIONS OF METHODS AND EQUIPMENTS FOR RECEPTION OF SINGLE-SIDEBAND SIGNALS, by M. G. Crosby. 36 p., diag., 1950. (Quart. Rpt. 4) (Contract W36-039-sc-38263)

215. Crosby Laboratories, Mineola, N. Y.
ENGINEERING INVESTIGATION OF METHODS AND EQUIPMENTS FOR RECEPTION OF SINGLE-SIDEBAND SIGNALS, by M. G. Crosby. 43 p., diag., 1950. (Quart. Rpt. 5) (Contract W36-039-sc-38263)
Design work on the single-sideband adapter unit, arranged for connection to a communications receiver, was completed to the stage where construction was begun on the first model. This model uses crystal single-sideband filters for sideband separation and will be capable of twin-channel operation accommodating a modulation band of from 400 to 3700 c. Testing of this model will start in the first month of the next quarter. A second model accommodating a 20-kc. bandwidth for single-channel single-sideband operation will utilize a phasing network type of design.

This paper bears on the problem of splitting a signal into two parts of like amplitudes but different phases. Constant phase differences are utilized in such circuits as Hartley single-sideband modulators. The networks considered here are pairs of constant-resistance phase-shifting networks connected in parallel at one end.


218. General Electric Co., Syracuse, N. Y. LONG RANGE COMMUNICATION EQUIPMENT 500 WATT SINGLE-SIDEBAND TRANSMITTER AN/FRT-7(XN-1). Final Engineering Report. 309p., illus., 1950. (Contract W28-099-ac-98) The transmitter will deliver at least 750 w. of average power continuously with reasonable linearity for signal envelope variations between 0 and 2000 w. for any operation in the 1.5- to 30-mc. range.

219. General Electric Co., Syracuse, N. Y. SINGLE-SIDEBAND ADAPTERS FOR NAVY MODEL RBC AND RDM RECEIVERS. Final Report. 52p., diags., Mar. 1950. (Contract W28-099-ac-98) The two adapters, operating from 115 v. 60 c., were to be similar to the Army adapter except for modifications which permitted reception of twin-channel single-sideband signals over an audio range of 100 to 12,000 c. Instead of 300 to 12,000, and allowed their use with RDM receivers at 455 kc. and RBC receivers at 400 kc.


222. Hamilton, G. E. and Artman, R. G. AN ANALYSIS OF SINGLE AND DOUBLE SIDEBAND TRANSMISSION. TV Eng. 1:22-24, July 1950. "A brief mathematical analysis of the double- and the vestigial single-sideband transmission modes is presented and applied to the problem of the detector frequency response. Results indicate that in the double-sideband case this response should respond to modu-
lating frequencies only and some attenuation can be tolerated, whereas for single-sideband work an infinitely wide detector response is required." Sci.Abs. 53B:4288, 1950.


Theoretical and practical considerations involved in the measurement of spectral energy distribution of television signals. Methods employed in making measurements include RF excitation of input of modulated amplifier, sine-wave modulation of transmitter and synthetic video signal modulation of the transmitter.


"The processes of single- and double-sideband modulation are discussed; the reasons for the advantages of the former are, namely: (1) improved s./n. ratio at the receiver (9 db); (2) less band-width per channel; (3) freedom from distortion due to selective fading and multi-path propagation. A triple modulation method is described which allows rejection of the unwanted sideband to be carried out at a point where the sidebands are well spaced allowing economical filter design. Block schematics of the transmitter and receiver are given. Examples are given of a 300 W (peak) transmitter and receiver installed on the 'S.S. Caronia' and a triple diversity receiver for land use. Up to six telegraph channels have also been satisfactorily used on a single single-sideband link." Sci.Abs. 53B: 3910, 1950.


The author attempts to answer some of the questions which present themselves during the design of a single-sideband receiver. The discrepancies which appear in the response of the receiver to a unit step are discussed theoretically in relation to those features of the frequency characteristics which give rise to them. The information is intended to assist the designer in setting a balance between economy and performance. The step-responses, obtained experimentally, of two typical receivers, are shown.

An important class of filtration problems in telecommunication is associated with frequency changing. It includes the generation and demodulation of single-sideband carrier channels and the elimination of image-frequency interference in heterodyne demodulators, such as the superheterodyne radio receiver or the conventional wave analyser.

Basic principles of a proposed system of radio communication in which several kilocycles of information bandwidth are transmitted in sequence in a narrow band on one side of a carrier, and interfering heterodynes are eliminated by shifting them to the unused side of the carrier.

Use of phasing method in single-sideband transmitters.

This first monthly report indicates that an orientation period and an attempt to get acquainted with various methods of intelligence transmission consumed the greater part of the time.

An outline of the chief problems and an indication of the topics to be investigated.

Progress report on reconstitution of the carrier; demodulators; 90° phase-difference networks; and questions pertaining to the reception of signals with phase-conscious modulation.
Theoretical work in connection with the analysis of the operation of a carrier reconstitution circuit employing a phase-sensitive detector and a reactance-tube controlled local oscillator; also, a report of a short experimental program to obtain data on intermodulation distortion.

Technical progress on demodulators; noise; and $90^\circ$ phase-difference networks.

Results of study of comparison of single- and double-sideband transmission.

A summary of findings relative to switched-diode demodulators.

The design procedure for a $90^\circ$ phase-difference network is presented and a schematic of the final network included.
Discusses effect of combined phase and amplitude error.

Reports progress of work on automatic frequency control of a regenerated carrier for the single-sideband receiver.

Technical progress is reported.

This is the fourth and final report covering an engineering research study of high-level single-sideband generation and the construction of two experimental models of a radio transmitter providing single-sideband operation over the frequency range of 1.5 to 30 megacycles and having a peak power capability of 500 watts.
The operation of the high-level transmitter is described and a detailed description of its component parts, including all circuit diagrams, is given.

241. Stanford University. Electronics Research Laboratory, Stanford, Calif.
The cascade connection makes possible the attainment of substantially improved rejection ratios. Provided that adequate performance can be realized in the remaining parts of the system, such as the modulators or demodulators, it appears that the phase rotation method can be made equal in performance to the best conventional band-pass filters as a means for obtaining sideband selectivity.


An investigation of the use of triodes in the high-level single-sideband balanced modulator circuit was undertaken.


Circuits for single-sideband generation, based on phase-modulation sidebands, are shown.


Results are presented of a study of the Taylor system of high efficiency modulation (supermodulation). This system produces conventional amplitude modulation and is simple. Further research is needed before the degree of linearity obtainable and the best operating conditions can be specified in advance.

245. Stanford University. Electronics Research Laboratory, Stanford, Calif. CONSTANT-PHASE DIFFERENCE NETWORKS AND THEIR APPLICATION TO FILTERS, by D. K. Weaver, Jr. 60p., illus., Oct. 28, 1950. (Tech. Rpt. 1) (Contract AF28(099)-83)

A report on a useful corollary application which became evident during the development of the theory of constant-phase-difference networks and their application to the generation, transmission and reception of single-sideband signals.

The theory of networks which realize a constant difference in the phases of two outputs, over a wide band of frequencies, in the equal-ripple or Chebyshev manner is here extended to the limiting case of zero error and zero bandwidth. This is the maximally-flat or Taylor type of approximation. The electrostatic potential analogy is used, with an appropriate conformal transformation, to develop the mathematical theory, and a design procedure is developed. For application to single-sideband systems, a comparison is made of the performance of these and of the equal-ripple type. The maximally-flat type offers no advantage, in fact is inferior, in this application.


An attempt to make the phase-equalization problem in 90° network single-sideband systems easier, by using more complicated 90° networks, has been made. Results indicate that practically no benefit is obtained by widening the frequency band over which 90° phase difference is approximated.


Work was begun on a filter design which uses no coils.


Summary reports of the various phases of work in progress are given. Included are a phase equalization design and transient response curves supplementing Report 7, and certain performance characteristics supplementing previous constant-phase-difference network characteristics.


Outlines current work. No special results are said to be ready for detailed reporting.
   Bibliography, p. 357-364.
   Single-sideband systems are mentioned in Chap. 14; Carrier generation for multi-channel carrier-systems; and in Chap. 17, Frequency selection.

   Description and operating principles, circuit description, installation information, operation, maintenance and trouble location procedures.

   Translated title: Single-sideband modulation.
   In German.

1949


   System finds broad application when carrier spectrum is crowded and when circuits exhibit high attenuation, high noise-level, or heterodyne interference.


   The advantages and disadvantages of several systems of detecting suppressed carrier single-sideband signals as applied to multichannel voice frequency communication equipment are to be
investigated. Equipment is to be designed for performance equal to or exceeding that of existing single-sideband receiving equipment with significantly simplified operation and adjustment. A demodulator function model and a carrier filter, signal, and a.f.c. function model were completed.


The selection of a single-sideband requires sharp frequency discrimination; and when this discrimination is achieved with minimum-phase structures, it is of necessity accompanied by delay distortion. The article describes how equalizers may be added to each terminal to make the phase characteristic approach linearity and so permit at least ten links to be operated in tandem without excessive distortion.


Details of the exciter and high-level amplifier units.


Reports results of operational study to date.

- 47 -
264. General Electric Co., Syracuse, N.Y.
LONG-RANGE COMMUNICATION EQUIPMENT, by G. M. Reinsmith.

The schematic diagram of the monitor unit as now constructed is enclosed with this report. This unit serves as a calibrator for the sideband generator as well as a demodulator of the transmitter output.

265. General Electric Co., Syracuse, N.Y.
LONG-RANGE COMMUNICATION EQUIPMENT, by G. M. Reinsmith.

The AN/GRC-25(XW-1) radio set which consists of a 500-w. single-sideband transmitter, a sideband adapter unit, and a diversity receiver system was completed. The AN/FRT-7(XN-1) transmitter will be the same as the AN/GRC-25(XW-1) transmitter with the exception of the modulating audio frequency range. It will consist of an exciter framework with 7 removable drawer-type units and a high-level framework housing a HV power supply, a power control drawer, and the high-level linear amplifier and antenna-matching RF equipment. The components are in various stages of development.

266. General Electric Co., Syracuse, N.Y.
LONG-RANGE COMMUNICATION EQUIPMENT, by G. M. Reinsmith.

The prototype version of the 0.5° error phase shift networks was tested. Bench measurements revealed that power supply impedance was an important factor in the determination of the differential amplitude characteristic. Modifications in the network cathode and plate resistors resulted in less than 0.5% differential amplitude error over the 100- to 12,000 cps frequency range. A rejection ratio of better than 40 db was obtained with the networks installed in the monitor unit and trimmed for optimum unwanted sideband rejection.

267. General Electric Co., Syracuse, N.Y.
LONG-RANGE COMMUNICATION EQUIPMENT, by G. M. Reinsmith.
The exciter unit has been aligned and operated satisfactorily. In operational checks of the high level portion of the equipment, the final amplifier was subject to spurious oscillation in the 20-to 30mc. frequency range under certain combinations of settings of the tuning controls.

268. General Electric Co., Syracuse, N.Y.

Trap circuits installed in the final amplifier stage successfully squelched parasitic oscillations that had been occurring. Except for the heat runs final tests of the recalibrated dummy H₂O load were completed for 1.5, 2.5, 4.1, 6.5, 9.9, 13.3, and 17.54 mc. A triggered parasite at 22.1 mc. occurring only during shock excitation, which set up voltages that caused flashing of the band-change switch, must be suppressed before the final tests can be resumed.


Single- or double-sideband or P.M. from one transmitter.


A description of a single-sideband exciter that uses one of the preadjusted audio-phase-shift networks.

271. Great Britain. Royal Aircraft Establishment, Farnborough, Hants. SINGLE-SIDEBAND COMMUNICATION FOR AIRCRAFT AND OTHER MOBILE SERVICES, by G.W. Barnes. 31p., illus., 1949. (Tech. Note 450)

The advantages of employing single-sideband technique for mobile, particularly airborne, R/T stations on high-frequency circuits are described. The general problems associated with single-sideband transmission and reception are examined and the use of a pilot carrier to provide a.g.c. and a.f.c. at the receiver is considered.


In German.
Translated title: Single-sideband method or frequency modulation in the telephony on power lines?

Discussion of the relative merits of the two systems, with particular reference to corona interference and to distortion due to sideband clipping in FM systems.


Tells of the first use of the system in marine communication.


Employs a single-sideband carrier system applicable to broadband carrier facilities.


In German.

"A theoretical treatment of the subject shows that no simple demodulation process can be applied. Investigation of the AM which occurs in single-sideband systems indicates that the phase swing is limited to <1.7 radians, so that only narrow-band modulation is possible. Formulas are given for determining the behavior of the demodulated low-frequency curves, and distortion is discussed. From these considerations, single-sideband FM appears to be impracticable for communication purposes." Inst. Radio Engrs. Proc. Abs. and Ref., no. 743, 1950.


In German.


Construction and adjustment details.

The system finds broad application when carrier spectrum is crowded and when circuits exhibit high attenuation, high noise level, or heterodyne interferences.


"An illustrated description, with block and circuit diagrams. The advantages of single-sideband operation are outlined and the application of the normal suppression method to these transmitters is discussed. The use of quartz filters reduces the number of frequency conversions necessary to three, which are effected at 84 kc/s, at 2520 kc/s and at a variable frequency. Each transmitter has a frequency range of 3.75–23 Mc/s and includes an automatic quick-action frequency-selection device. C.w. and a.m. telegraphy, and telephony operation can also be arranged; in single-sideband working a 'pilot frequency' signal is transmitted for modulation purposes at the receiver." Wireless Eng. 27:777. 1950.


Gives basic techniques for adjusting amplifiers used in single-sideband transmitters.


The article describes an exciter, built mostly of junk-box parts, that is suitable for the average ham who might like to try single sideband with a minimum of cost and effort.


In French.

Translated title: An arrangement of double diversity for radio reception by single sidebands.

Summary: "The author recalls the principle of diversity reception and sums up briefly its applications in single-sideband receivers. He then describes the principle characteristics of the system pertinent to S.R.F. In this system, the reference level is furnished in the two bands by the mean level of the carrier wave so that the commutation operates independently of the modulation transmitted by the sidebands."

- 51 -

Use, advantages, designer and performance of single-sideband telephony on the Cunard White Star liner Caronia, believed to be the first passenger vessel fitted with transmitters and receivers for single-sideband telephony.

285. Stanford Research Institute, Stanford, Calif.

The purpose of this investigation is to thoroughly investigate the problem of generating a single-sideband, suppressed-carrier, high-frequency radio signal applicable to multichannel, voice-frequency military communication.

286. Stanford Research Institute, Stanford, Calif.
A RESEARCH INVESTIGATION OF METHODS AND EQUIPMENT FOR HIGH-LEVEL SINGLE-SIDEBAND GENERATION IN THE FREQUENCY RANGE OF 1.5 TO 30 MEGACYCLES. 25p., diags., June 6, 1949. (Quart. Prog. Rpt. 2) (Contract W36-039-sc-38199)

This report covers all activity during the second quarter of an investigation into a method of generating a single-sideband suppressed carrier radio signal at a high power level in the 1.5 to 30 megacycle region. Progress is discussed under the following headings: Laboratory facilities and special test equipment; wide-band audio-frequency 90° phase-shift networks; measurement of audio phase shift; radio-frequency 90° phase shift networks; selection of tetrode; screen modulator; and automatic tuning control and alarm circuitry.

287. Stanford University. Electronics Research Laboratory, Stanford, Calif.
COMMUNICATION TECHNIQUES (MODULATION) PROJECT, by O. G. Villard, Jr. 18p., illus., 1949. (Quart. Prog. Rpt. 1) (Contract W28-099-ac-13l)

A study was made of the possibility of applying negative envelope feed-back to balanced modulators for the reduction of spurious sidebands arising from nonlinear distortion. Tuning adjustments in the feed-back loop were eliminated by means of a novel aperiodic exalted-carrier detector connection. Results suggest that this technique may be applied to high-level single-sideband generators. If successful, this may make possible high-level single-sideband transmitters whose performance is comparable to the best low-level equipment produced to date.

Reports findings affecting single-sideband systems in connection with the 90-degree network investigation.


A new high-level, high-efficiency modulation system has been developed, having as its distinguishing features a carrier-level efficiency and an ease of adjustment and operation quite comparable to high-level plate modulation. The combination audio oscillator and band-pass filter should be useful in single-sideband voice reception.


This contract is an extension of contract W28-099-ac-131 which included a study of single-sideband communication using 90° phase-shift networks instead of filters, and of W36-039-sc-38199 concerned with the design and construction of single-sideband transmitters. Under the present contract, phase distortion in single-sideband receivers is to be studied to aid the design of radio receivers for phase-sensitive systems.


Methods were sought for making the through or transmission phase characteristic sufficiently linear with frequency so that wave forms could be transmitted. Theory indicates that, because of certain unique properties of the 90° phase-difference function, any unit design which includes phase equalization as well as the 90° feature can be broken down into networks of the present type combined with an equalizer which is the same in each path. The equalizer, then, would be equally effective if placed before the branching point, and apparently straightforward equalization techniques may be helpful.
The use of an all-pass phase equalizer in series with the 90° networks of a single-sideband transmitter is being investigated. The through-phase characteristics of the standard 90° network design made for the Stanford Research Institute transmitter were selected as typical, and data were obtained as to the order of magnitude of the complexity of the network which would be required to equalize this phase characteristic to be approximately linear with frequency.

High-quality equalization of the phase characteristic of a specific 90°-type of single-sideband system is considered. Application of the 'condenser-plate' technique, both (a) at audio frequencies and (b) partly at radio frequencies and partly at audio frequencies, indicates the need of an unreasonably large corrective network in each case.

**1948**

A description of a new super-selective i.f. channel for use with present receiver.

An uncomplicated s.s.s.c. exciter that makes use of a static wide-band audio-phase shifter developed by Westinghouse for single-sideband carrier-current equipment.

Summary of convention paper.
Part I. Introduction and description of receiver apparatus.
Part 2. Description of transmitting apparatus.


"A unit for attachment to communications receivers with an i.f. of $\sim 455$ kc/s and for use with modulated or c.w. signals is described. Either sideband can be used, or alternatively double-sideband reception can be obtained with a locally-reinforced carrier to reduce selective fading. The unit, which contains 14 valves, comprises an oscillator, two detectors with phase shifters and one a.f. stage. It is fed from the least i.f. stage of the receiver and itself feeds into the receiver's audio system. For satisfactory operation, the receiver's i.f. amplifier must be correctly aligned and the local oscillator free from slow drifts, erratic jumps and f.m." Sci. Abs. 52B: 912, 1949.

299. General Electric Co., Syracuse, N.Y.
GROUND-TO-AIR LONG-RANGE COMMUNICATION EQUIPMENT. Interim Engineering Report, January 1948. 5p., 1948. (Contract W28-099-ac-98)

The report covers 900 phase shift circuits; selectable crystal oscillator and frequency converter; low level linear amplifier; sideband generator unit; and single-sideband adapter.

300. General Electric Co., Syracuse, N.Y.

Discusses laboratory tests of the sideband generator units.

301. General Electric Co., Syracuse, N.Y.

Reports progress of work on single-sideband transmitter and adapter.

302. General Electric Co., Syracuse, N.Y.
Evaluation of the generator indicates that the high-level system of single-sideband generation seems to be a relatively simple system. Careful adjustment will yield a performance characteristic which is quite comparable to present single-sideband systems.

303. General Electric Co., Syracuse, N.Y.  
Includes a schematic diagram for the sideband selector unit.

304. General Electric Co., Syracuse, N.Y.  
Further report on details of study.

The principles involved in s.s.s.c. transmission and reception.


In this article on design trends it is stated that since single-sideband transmission has been standardized, means must be provided for suppression of the unwanted portion. Progressive circuit attenuation or vestigial sideband filtering is currently employed for this suppression. In this method the r-f bandpass characteristic of all amplifiers following the modulated stage are adjusted so the upper sideband only is passed.

In field tests of a number of frequency division multichannel systems for use in h-f range (3 to 30 Mc) it was found that f.m. subcarrier channels in conjunction with single sideband and space diversity provided the best method of those tried.


- 56 -
Amateurs and DX-ers can enjoy advantages of single-sideband reception without using complex equipment through use of the Norgaard system of single-sideband selectors.

The design, construction and operation of a single-sideband suppressed-carrier transmitter are described. Intermediate frequencies of 9 kc/s and 550 kc/s are used and the transmitted frequency is 14.2 Mc/s. The two higher oscillator frequencies are crystal-controlled and each frequency stage has a balanced modulator and filter.

Discussion of practical methods of generating a single-sideband suppressed-carrier signal without the need for sharp filtering and multiple heterodyning. One of the sidebands is removed by a process in which two audio channels with a constant phase difference of 90° are balanced.

By using an automatic "lock-in," easy reception of an s.s.s.c. signal (with a small amount of pilot carrier) can be obtained. Tells how the system works and gives pertinent information for its construction.


Developmental history since 1915.


- 57 -
Full circuit details are given for the General Electric single-sideband selector. Principles of operation are discussed with references to the work of Villard and Dome. The selector unit is connected to the last i.f. stage of an existing AM receiver by means of a small probe and a short length of low-capacitance shielded cable.

Description of a super-selective i.f. channel for use with present receiver.

The applications of the tetrode to single-sideband transmission.

Illustration and description of the Millen adapter unit.


322. Stanford University. Electronics Research Laboratory, Stanford, Calif.
Activity during the period was chiefly concerned with further study and evaluation of the four-tube high-level single-sideband generator.

323. Stanford University. Electronics Research Laboratory, Stanford, Calif.
Reports on a further test of the single-sideband plus carrier system and an investigation of the YRS single-sideband selector.

X-cut crystals are used in multiple-section filters for the upper and lower sidebands and the carrier frequency. The carrier filter
has a passband 16 cycles wide between 3-db points and the sideband filters are flat within 0.6 db for nearly 6 kilocycles.

325. TETRODES IN SINGLE-SIDEBAND TRANSMISSION AND IN CLASS C FM AND AM APPLICATIONS. Communs. 28:22-23, 36,illus., Dec. 1948.


After an introduction, a short description is given of the equipment developed before 1940, followed by a survey of the principles of the modern equipment. The way in which the automatic tuning in the receiver is accomplished is described in detail. A summary is given of the advantages of the modern equipment with respect to the earlier art. In an appendix, some theoretical considerations are given with respect to the automatic tuning control; particularly, the conditions for a stable circuit are derived.

Approximately the same article, in Dutch, with English summary appears in Tijdschr. ned Radiogenoot 12:127-149, Jly.1947.


Eliminating the unwanted sideband by phase-shift networks.


It is the purpose of this paper to describe a transmitter of the phase-rotation type in which the single sideband is generated at high level and good efficiency directly in the final stage.


Explains why single-sideband transmission offers an opportunity for a big improvement in receiver selectivity.


331. Villard, O. G. SIMPLIFIED SINGLE-SIDEBAND RECEPTION.

Electronics 21:82-85, illus., May 1948.

- 59 -
Accessory designed for use with a conventional communications receiver exhibits advantages when receiving ordinary code signals, as well as single-sideband phone. Selectivity is approximately doubled by employing a demodulating oscillator, balanced detector, two 90-degree audio phase-shift networks and a low-pass filter.


A pair of balanced modulators in a phase rotation system may be used to give single-sideband output.

1947

(Memo Rpt. WLERL 1-7)
Prepresents information on the theory of single-sideband generation and concludes that as a result of the advances being made in single-sideband circuitry and in the general miniaturization of components, single-sideband transmission systems will provide increasingly superior and more reliable military communication, including ground-to-air and air-to-ground systems, as compared with double-sideband transmission.

In this general review of communications mention is made of the special attention given to the development and production of single-sideband equipments.

The choice of upper or lower sidebands, p.165.

337. Bray, W.J., Lillicrapp, H.G. and Lowry, W.R.H. THE DESIGN OF TRANSMITTER DRIVES AND RECEIVERS FOR SINGLE-

The following equipment is described: (a) a low-power drive stage; (b) a monitor receiver which enables either channel of the r.f. signal to be demodulated for tests of quality and distortion; (c) single-sideband receivers for single-aerial and triple-diversity-spaced-aerial operation at the receiving end of a radio link. The design, layout and performance of a typical receiver are discussed.


Examples are given of the use of the equipment to assess the merits of double-sideband, single-sideband and the frequency-modulated transmission systems with telephony or telegraphy modulation, under conditions of severe selective fading and high noise level.


A tabulation.


Discussion of the advantages and requirements of such a system and of the receiving equipment at the Australian terminal of the London and San Francisco circuits.


Channel and carrier filters for single-sideband receiver, p.917.


The period was spent, essentially, in the construction of breadboard first versions of single-sideband generating, amplifying, and receiving circuits.

343. General Electric Co., Syracuse, N.Y. GROUND-TO-AIR LONG-RANGE COMMUNICATION EQUIPMENT.

- 61 -

The single-sideband transmitter study for the month of November was devoted to the design and selection of components for the high power R.F. stages; the rectifiers and and control portions of the transmitter.

344. General Electric Co., Syracuse, N.Y.

Work was devoted to component ordering for the higher power portions of the transmitter, to further investigation of 90° audio phase-shift circuits, and to further laboratory construction and test of the low-level R.F. portions of the transmitter.


Distortion of a modulated carrier in a transmitter due to varying input impedance of the power amplifier is avoided by using screen-grid driving valves with an impedance transforming network.


In the section, on p. 418 entitled "Effect of valve operation and circuit design on suppression of unwanted frequencies" mention is made of single sidebands.


Essentially the same article appears with title: A NEW SINGLE-SIDEBAND CARRIER SYSTEM in Elec. Eng. 66:549-552, illus., June 1947.

This new method of single-sideband generation is based on the frequency addition principle. Apparatus consists of linear modulators combined with wide-range phase-splitting circuits to produce the signals.

Selectable single-sideband reception through operation of heterodyne-eliminating receiver.


An authoritative article outlining the expansion of the long-distance point-to-point system during the war years and some of the advances in technique which have made for more reliable communication. The single-sideband system is described in detail.


Work on the modulation system was finished during this period. It is stated that the low distortion and wide frequency response obtainable with this method of modulation are quite remarkable.

As a sideline, during the period, a system of high-efficiency modulation was tested out and demonstrated satisfactorily.


Services covering research and investigation leading to a system for obtaining low-level amplitude modulation with high power r-f amplification comparable in efficiency to Class "C" operation and capable of 100 % modulation with minimum distortion.

History of the project; experimental transmitter; design of system components; and ideas and proposals including modulating system, method of obtaining 90-degree phase-shift; high-level high-efficiency single-sideband generator; and single-sideband generation with phase-amplitude circuit.

Included as an appendix is a report on proposed system of high-efficiency modulation, by F. E. Terman.


1946


Applicable to single-sideband telephony accomplished directly at the final carrier frequency without multiple modulators or sharp cutoff filters.


This paper describes laboratory tests of certain carrier telegraph methods, including the single-sideband method, to determine their relative advantages from the standpoints of signal speed, and sensitivity to level change, carrier frequency drift, interchannel interference, and line noise.

Single-sideband telegraphy has an advantage of providing somewhat higher speeds without increasing the band width. Whether it holds much promise for any general application in multi-channel systems utilizing narrow bands and moderate signal speeds is questionable in view of certain difficulties. For a single-sideband high-speed circuit, single-sideband telegraphy might be found worth while from the standpoint of economical use of the frequency spectrum.


Comparison of reception by means of the Musa and normal single-sideband equipment.

356. Rhode, S. NEW CARRIER-FREQUENCY SYSTEMS FOR TELEPHONY AND REMOTE METERING AND CONTROL ON POWER LINES. Ericsson Rev. 23:2-34, 1946.

Single-sideband working is used with carrier frequencies in the band 50 to 150 kilocycles.

1945

   A comparison of a-m, f-m, and single-sideband systems for power-line carrier transmission.


   Balancing out the undesired sideband in a vacuum-tube circuit eliminates need for selective filters in power-line carrier systems for telemetering or voice communications.

361. Landon, V. D. THEORETICAL ANALYSIS OF VARIOUS SYSTEMS OF MULTIPLEX TRANSMISSION. RCA Rev. 9; 287-351, June, 1945; 433-482, Sept. 1945.
   Single-sideband systems are included in the discussion.

   The amplifier described is designed to operate as a 'class B' amplifier for transmitting either single-channel double-sideband or twin-channel single-sideband types of transmission.

   Brief description of system developed by Westinghouse engineers.

364. War Department, Washington, D. C.
   RADIO RECEIVING EQUIPMENT, SINGLE-SIDEBAND (WESTERN ELECTRIC TYPE D-99945). 9 parts, illus., May 24, 1945. (TM 11-884)
   Includes Western Electric Co. Bulletins 982, 997P, 1093; Federal Mfg. and Eng. Co. Bulletin; X 75053-19C (Spl.) oscillator per D-166636 (moisture resistant); X-75056 Hickok model 560(Spl) tube tester per KS-9237; BSP. AB22, 334-100E loudspeaker equipment; BSP. C54. 501-100E loudspeaker-installation and maintenance; Maintenance parts.

365. Western Electric Co., New York, N. Y.
   RADIO TRANSMITTER D-156000. 3v., 1945. (Instruction B. 985)
   Describes radio receiving, single-sideband equipment.
1944

   In German.
   Translated title: Transmission of amplitude and frequency modulation vibrations by short wave.

   Compact test unit to be used with single-sideband exciters having 90-degree phase-shift networks.

1943

   In German.
   Translated title: Sideband asymmetry in amplitude modulation.

   This paper deals with an investigation into some theoretical and practical aspects of the partial suppression of one or both sidebands in connection with asymmetric-sideband television broadcasting channels.

   In German.
   Translated title: Arrangement for single-sideband transmission.
   "A Siemens & Halske patent, D. R. P. 730,416, applied for 15/11/40 to make the frequency requirements for the transmission of telegraphic and television signals, etc., only about half as great as in ordinary alternating-current telegraphy, the carrier frequency is displaced from the middle of the transmitted frequency band. The transient process can then be resolved into a rapid and a slow component, the latter being suppressed." Wireless Eng. 21:289, June 1944.

1942

   A unique feature of the transmitter equipment is that while double-sideband currents (suppressed carrier) are supplied to the two sideband antenna pairs, the power amplifiers employed in the sideband amplifier channels amplify only single-sideband currents.


1941

   The short-wave single-sideband receiver is discussed on p. 114.

375. Brown, G. H. A VESTIGIAL SIDEBAND FILTER FOR USE WITH A TELEVISION TRANSMITTER. RCA Rev. 5:301-326, illus., 1941.
   Records tests and observations made at time of installation in March 1939.

   In German.
   Translated title: The Telefunken single-sideband transmitter.
   The transmitter under construction is described and some of the problems connected with it are discussed.

In German.
Translated title: Planning and development of a single-sideband transoceanic radiophone connection.

The article discusses the German transoceanic connection; radio-phone connections in general; particular characteristics of the single-sideband method; preparations for the single-sideband connection; development of the German transmitting and receiving equipment; and experiences with the single-sideband connection.

In German.
Translated title: Single-sideband transoceanic radiophone connection.

Intermediate frequency equipment of transmitter and receiver serves for focusing the calls for transmission at much higher frequency and vice versa for defocussing when received. This equipment is described in detail and is shown in illustrations.

In German.
Translated title: The Telefunken single-sideband receiver for two channels.

The construction, circuits, operation and performance of the receiver are described. The more important differences from ordinary receivers are pointed out. The wave-length is 14-60 m. It permits either the reception of two simultaneous single-sideband talks, or of a normal two-sideband talk.

Briefly describes a heterodyne rejection circuit, semi-automatic in operation, and capable of removing several heterodyne beat-notes simultaneously.

A description of various types of filters. In radio systems quartz filters have been used extensively in separating one sideband from the other in single-sideband systems.

In German.
Translated title: The low-frequency terminal equipment for a new transoceanic radiophone connection.
This article includes the results of tests of a new single-sideband connection.

"The problem of building a filter of ladder or lattice type wherein the elements are replaced by coaxial lines is shown to be largely one of geometrical arrangement. A method of designing and constructing such filters is described. Using this procedure, an experimental filter of the ladder type has been built for the television channel of 66 - 72 megacycles. The cutoff sharpness at the lower edge of its frequency range is 32 db per per cent of frequency change. This can be achieved with a very compact filter structure. The general performance and range of usefulness of this filter type in television channels is discussed." - Summary.

"Unsymmetrical sideband problems are met in frequency modulation and single-sideband transmission. There has developed the urgent need of a simplified procedure for their solution. The 'vector envelope' of a modulated signal is reviewed with special attention to the simple cases of amplitude, phase, and frequency modulation, and of a single sideband. From this is developed the concept of the 'zero-frequency carrier' with combined amplitude and angle modulation. The solution is valid for any carrier frequency much greater than the total width of sidebands in the signal, regardless of whether the carrier is present. It yields directly the envelope of the envelope of the signal, as detected by a rectifier. It is applied to the general case of steady and transient modulation components. The simplified procedure is outlined in simple terms after rigorous derivation. It involves merely stating the input
modulating signal relative to the zero-frequency carrier, putting it through the low-pass analog of the band-pass filter, and deriving the output modulating signal directly."

1940


   The deformations which typical television transients suffer in single-sideband systems are shown.


   Gives experimental evidence that, for a given bandwidth, single-sideband transmission is distinctly superior to double-sideband in picture transmission. It also gives a theoretical discussion which indicates that this is not inconsistent with the observed fact that oscillograms with single-sideband transmission show considerable distortion.


   Summary only, indicating optimum conditions approached when filter slope in region of carrier frequency is zero.

- 70 -
Patent no. 2,211,040 issued August 13, 1940. A system for producing and amplifying two sets of sidebands which are in phone quadrature.


1939


For a transmission with two independent single-sideband speech channels occupying about the bandwidth of one double-sideband transmission.

Includes discussion of single-sideband reception.


An examination of theoretical justification for adoption of selective sideband transmission in order to increase the picture detail which can be transmitted in a frequency channel of given width.

In German.
Translated title: Theory and technique of single-sideband telephone.

"Single-sideband transmission with complete or partial carrier suppression for radio telephony or television as compared with double-sideband transmission offers great advantages. The principle one is that the single-sideband transmitter possesses telephonically a considerably higher effective power than a double-band sender. Further, only half the channel breadth is required, so that the pass range of the receiver can be reduced by half and the disturbance level is lowered to 1/2. With a single sideband with suppressed carrier, by superposing a suitable carrier amplitude at the receiver, the influence of the disturbance level can be still further lowered. Further, with carrier-less single-sideband transmission on short waves a certain secrecy is attained as only very accurately balanced crystals with high frequency constancy can be employed. The paper investigates how effectively the single-sideband telephone transmitter with radiated carrier can be controlled to give satisfactory reproduction of speech at the receiver. The theoretical enquiry is directed to the question what distortion by linear and quadratic rectification may be regarded as the practical limit. Further, the question whether disturbance by telephone transmitters operating on neighboring frequencies is essentially smaller than with double-sideband transmitters is experimentally investigated." Sci.Abs. 42. B.1732, 1939.


"Given the phase and amplitude characteristics of a filter, a graphical method is presented for deriving the phase and amplitude characteristics of the modulation envelope or video frequency response when a modulated carrier is impressed. Sources of distortion are briefly discussed. Several filter structures are considered as to their suitability for use in attenuating one sideband of a television signal. Radio frequency phase and amplitude characteristics are given, with notes as to the physical realisability of the structures. Resulting video frequency phase and amplitude characteristics are derived after demodulation, and in some cases the video frequency transient response resulting from a suddenly impressed carrier is given. Design formulae are given for a filter using transmission lines as circuit elements. Some problems in the application of a filter to the transmitter are considered. The gain of amplifier stages is treated for many types of video and radio-frequency amplifiers, for single- and double-sideband use, and for one- and ten-stage amplifiers, when meeting certain tolerances to a fixed maximum modulation frequency." Sci.Abs. 42. B:2217, 1939.
Analysis of sideband cutoff due to resonance characteristics; filtering action on higher harmonics; and modulation distortion due to phase rotation of sidebands.

Cites great advantages over single-sideband transmission.

Attempt to find practical system using cancellation principle for suppression success to more than -40 db.

The effect of detuning a transmitter to suppress partially one sideband and increase the width for the other sideband is investigated.

Discusses single-sideband modulator.

In German.
Translated title: Observations regarding transmission of television by one single sideband.

1938

"It is shown that if two separate amplifiers, each with its own modulator, are excited by a common oscillator and operate into a common aerial and if the frequencies of the amplifiers are displayed in phase, then by the use of a suitable detecting circuit
in the receiver the two signals can be separated. It is also shown that the common carrier frequency or one of the sidebands in each channel, can be suppressed. Furthermore, it appears that the width of the band transmitted remains the same whether the carrier frequency is modulated by one only or by two signals simultaneously. Practical transmitting and receiving circuits operating on the above principle are discussed." Wireless Eng. 16:102, Feb. 1939.


The volume variations due to fading on this circuit are not fully compensated by normal methods of automatic gain control on the receiver, and the provision of a constant volume amplifier at the output of the receiver to remedy the defect is discussed. Two types of amplifier, one of which was developed for another purpose and was used experimentally, are described.


As each new type of carrier telephone system has been developed it has been assigned a letter of the alphabet. These various systems are reviewed from a historical standpoint. Several are single-sideband systems.


Single-sideband transmission, p. 399-400.


Includes analysis of distortion due to asymmetry leading to design of special network; calculation of reduced sideband splash; comparison of Eckersley system and Koomans system.


The object of the asymmetric sideband system of transmission is to cut away part of one sideband without introducing audible harmonic distortion.
This paper presents a quantitative analysis which forms a guide to practical design.

The system described is designated the Type H. Reduction in size and provision for operating on a-c supply simplify its installation, and its portability makes it well suited to provide emergency circuits.

"Theory and experiments on combination of (e.g.) amplitude and frequency modulation, involving the splitting of the band into two halves, one being inverted and displaced into the other." Wireless Eng. 16:195, Apr. 1939.

Device applied to suppressed-carrier systems both at the receiving and transmitting station.


Describes the brief outline of the single-sideband radio transmitter and receiver and also gives the experimental results of the partial characteristics of each equipment and the overall characteristics of the radio circuit between Tokyo and Kagosima.

There is described briefly a short-wave single-sideband system which has been developed for transoceanic radio-telephone service. The system involves the transmission of a reduced carrier or pilot frequency and is designed to include the testing of twin-channel operation wherein a second channel obtained by utilising the other sideband. The paper indicates the reasons which led to the selection of this particular system and discusses at some length those matters which require agreement between the transmitting and receiving stations when single-sideband transmission is employed. Sci.Abs. 42. B. 393, 1939.

    Also published as Bell Telephone Sys. Tech. B-1114, 1939.

    An investigation was conducted to determine both theoretically and experimentally the advantages and disadvantages of selective sideband as compared with double-sideband transmission of telegraph and facsimile signals.

    In German.
    Translated title: Experimental investigation of the displacement of a frequency band of theoretically arbitrary width through a desired phase angle.
    Concerns displacing the phase of a single auxiliary carrier frequency on which is impressed a single-sideband modulation by the given frequency band.

    In German.
    Translated title: The restoration of the sideband suppressed in single-sideband modulation.
"Theoretical and experimental treatment. It is found that by the addition of an auxiliary oscillation of twice the carrier frequency, and subsequent rectification, an image of the original sideband, true in frequency and phase, is obtained with practically no distortion. The use of a 'ring' modulator in place of an ordinary rectifier enables the first sideband to be suppressed at will." Wireless Eng. 16:142, Mar. 1939.


In Russian.
"In a paper in another journal it was suggested by the writer that various systems of modulation could be compared on the basis of the audio output given at the receiver. This method of comparison can easily be applied to two double-sideband modulation systems (with or without transmission of the carrier) since in this case the same output will be obtained so long as the power in the sidebands remains the same in both cases. It is shown, however, that when two modulation systems are compared with single- and double-sideband transmission respectively, the same audio output will only be obtained if the power in the single sideband is twice the power in the two sidebands." Wireless Eng. 16:84, Feb. 1939.

1937


In this review of the technical side of the development of trans-oceanic radio telephone the following statement appears: "The transmission improvement of about 9 decibels (about 10:1 in power) offered by single-sideband suppressed-carrier transmission has been delayed in its application to short-wave transmission partly because of the high degree of precision in frequency control and selectivity necessary to its accomplishment. In recent years successful apparatus has been developed and proved satisfactory in trials. The introduction of single sideband into commercial usage is already in progress.

Describes a system developed to fit the fields of use in a telephone plant. The single-sideband transmission is employed.


In his history of radiotelephony the author states: "Related to both vacuum tubes and the band conception were Carson's analysis of the modulated wave into the component carrier and sidebands and his invention of single-sideband transmission made as far back as 1915, and the general extension of the signal-band idea to high frequencies, which has meant so much to both wire carrier-current telephony and radiotelephony."


The conditions for a distortionless h.f. transmission are set forth and the various causes of disturbance of sideband symmetry liable to be present in valve transmitters are described.

A more complete author's summary may be found in Wireless Eng. 14:500, Sept. 1937.


Various methods of obtaining simultaneous service are discussed. The effect of linear and square-law detection used with single-sideband and double-sideband transmission of the range tone have been analyzed. The single-sideband method appears to offer the most practical solution to the problem when used with a linear detector.


Discusses single-sideband and suppressed-carrier transmission.


Also in RCA Rev. 1:19-35, Jan.1937.


In German.
Translated title: Experiments on single-sideband modulation with frequency divergencies of replaced carrier at the receiver.

1936

   In French.
   Translated title: Radio-electric communications.
   Ch. III, p.128-136, in particular.

   Analysis prompted by results in suppressed-carrier transmission; possible importance in i.f. circuit design in superheterodyne receivers.
   See also editorial on p. 517-518.

   The system makes use of single-sideband transmission.


   For carrier-current single-sideband suppressed carrier working.

   Editorial. See also Item 435.

   In Russian.
   Author's summary: "The analysis of the radio-telephone transmission system with carrier and one sideband is given. The expediency of its application to broadcasting is considered. It is shown that in this case the ratio of signal intensity to interference, on changing from the usual system to the single-sideband transmission is reduced 2.7 times. Methods are given for reducing distortion and interference when receiving single-sideband transmission based on the decrease of
modulation in the receiver. It is shown that by the use of this method the selectivity of the receiver is greatly increased. The problem of the modulation and interference effect on the synchronous channel of the receiver is investigated; it is shown that synchronisation will be stable even when the modulation exceeds 100%. The tendencies of further scientific research work on single-sideband broadcasting are described." Wireless Eng. 14:54, 1937.

1935

Refers to suggestion to transmit only carrier wave and one set of sidebands, thus minimizing spectrum overlap.
See Item 442.

Includes discussion of transmission of a carrier and single set of sidebands; and phase modulation in single-sideband broadcasting.
See Item 441.

This invention relates to a method for dividing a band of frequencies and more especially to a method for dividing a frequency band by the use of phase discrimination without the use of electrical selection.

Describes the construction of a short-wave single-sideband carrier system of radio transmission. It also reports the results of comparisons made between this system and an ordinary short-wave double-sideband system between England and the Unites States. It was found that the single-sideband system gave an equivalent improvement in radiated power over the double-sideband system averaging eight decibels.


1934


The carrier apparatus described, p. 291-294, is single-sideband carrier suppressed, with perfectly synchronized carrier frequencies of 40,000 c. p. s.


In German.
Translated title: Germany's broadcasting service as a technical problem.

"In the subsequent discussion, p. 705-707, Schröfer refers to the work of Koomans in Holland on carrier and single-sideband transmission, and the attractions of such a plan." Wireless Eng. & Exper. Wireless 11:572, Oct. 1934


This article is referred to by Polkinghorn and Schlaack as the one which supplies information on construction of a low-frequency lattice-type filter using quartz crystals as elements in order to obtain the necessary attenuation to the carrier frequency and one sideband while passing the other sideband.

The system described was developed as a result of appointment of a C.C.I.R. sub-committee.

Reviews the general subject of modulation and sidebands in view of possibility of single-sideband broadcasting.

1933
In German.
Translated title: Arrangement for single-sideband modulation.
German patent No. 500,226, published September 29, 1932, by J. von Plebanski.

For single-sideband carrier suppression working.

The various components and their functions in the single-sideband receiver are described. The receiver characteristics are shown graphically.
The receiver was constructed by the Marconi Company for the Post Office and installed at Baldock.

In French.
Translated title: Single-sideband radiotelephony.
A theoretical discussion of single-sideband radiotelephony is given. The circuits and methods of using single-sideband telephony are then discussed.

The possibility of single-sideband radiotelephony as a commercial project and the various problems encountered in such a system are
discussed. It is shown that in the absence of selective fading the
question of synchronizing is fairly simple. Some experimental re-
results are given.

458. SIDEBANDS OCCURRING IN FREQUENCY MODULATION.  Electronics
Review of the Washington Engineering Experiment Station Bulle-
tin on experiments in frequency modulation. Authors are E. D.
Scott and J. R. Woodyard. The Bulletin number is 68 for 1933.

459. SINGLE-SIDEBAND RADIO TELEPHONY.  Elec. Rev. 112:157-158,
Feb. 3, 1933.
Further information on the design and construction of a long-wave
single-sideband telephone receiver for transatlantic working.

460. LA TRANSMISSION RADIOTÉLÉPHONIQUE À ONDES COURTES A
BANDE LATERALE UNIQUE ET AUTRES SYSTEMES.  Soc. Franc.
In French.
Discussion of report by M. E. Deloraine.
Relates to single-band telephony.
For complete report, see entry under Deloraine, Item 462.

1932

461. Colebrook, F. M.  A NOTE ON THE FREQUENCY ANALYSIS OF
THE HETERODYNE ENVELOPE: ITS RELATION TO PROBLEMS
The analysis shows that a single-sideband system of broadcast
transmission would not give, on rectification, a faithful reproduc-
tion of the original modulation, but would give rise to a number of
extraneous difference frequencies, in addition to the introduction
of harmonics.

462. Deloraine, E. M.  LA TRANSMISSION RADIOTÉLÉPHONIQUE À
ONDE COURTES A BANDE LATERALE UNIQUE ET AUTRES SYS-
In French.
Translated title: Short-wave radiotelephony transmission by
single-sideband and other systems.
Bibliography, p. 1008-1009.

Author's summary: "It is shown that single-sideband Morse transmission, if practicable, would relieve the present long-wave spectral congestion. Methods are developed whereby the wave shape of the single-sideband signals can be visualised when the original message envelope is given, and it is shown that the prolonged transmission of true single-sideband signals would in general necessitate the radiation of infinite amplitudes. Wave forms of approximations to single-sideband signals which evade this difficulty are determined: the wave form of the original message can be recovered without distortion from these 'asymmetric sideband' waves, the use of which, however, requires more power and also greater crest amplitudes than normal double-sideband transmission. The production and reception of asymmetric sideband waves is discussed."


In German.

Translated title: The application of the single-sideband system in short-wave technique.

After discussing difficulties and advantages of the single-sideband system, a detailed description is given of the equipment used in successful experiments recently carried out by French and Spanish interests.


In German.

Translated title: Frequency pass factor (ratio of amplitude of anode current or potential for sideband to that for carrier wave) in telephony transmitters with master drive.


Continuation of discussion in the author's "A study of wave synthesis by mechanical means, IV." See Item no. 469.
In French.

Description of apparatus used in a demonstration near Paris when speech was received from Madrid which was clear, intelligible, and of good and constant volume.

In French.
Translated title: The radiotelephone system of communications using single sideband applied to short waves.
"Describes in some detail experiments carried out between Paris and Madrid, using the single-sideband system of modulation on a wavelength of about 15 m. Successful results were obtained." Sci. Abs. 35B:367, 1932.

"The new system was demonstrated on May 21 at the experimental radio station of Le Matériel Téléphonique at Trappes (Paris). The difficulty of obtaining good synchronisation between the suppressed carrier at the transmitter and the local oscillator at the receiver is overcome by transmitting a continuous radio-frequency pilot wave in addition to the speech sideband, and this pilot is used at the receiver automatically to synchronise the frequency of the local oscillator. The pilot frequency lies some 400~ outside the speech sideband, which has a breadth of some 300~, and thus avoids any appreciable increase in total bandwidth. The bandwidth of the pilot itself is about 30~ to cater for a maximum fluctuation of + 15~ of the carrier frequency in a period during which the synchronising circuit has not had time to take up a new stable position. The
results show a commercial circuit with good quality and no interruption." Sci.Abs. 34B:2185, 1931.

1930

A discussion on the question of whether unequal fading of modulated component and carrier can occur in single-sideband transmission with carrier re-introduced in the demodulator.

Proposes to overcome limitations in filter construction by employing a method of suppressing the sideband or side frequency which involves the use of a "balancing out" effect for the elimination of the undesired components.

In this evaluation of the intelligence-carrying possibilities of radio facilities, it is indicated that single sideband allows for tremendous potential expansion.

1929

"Apart from the usual transmission methods (single-sideband: carrier and both sidebands) there should be a third, employing the carrier and one sideband which should have the advantage of requiring no carrier replacement at the receiver, as in the first system, and a width of filter only half that required by the second system. The writer examines the theory of such a third system and describes his experimental confirmation of the conclusions." Wireless Engr. and Exper. Wireless 10:502, Sept.1933.
475. Shea, T. E. TRANSMISSION NETWORKS AND WAVE FILTERS.  
Single-sideband transmission, p. 20.

1928

476. Affel, H. A., Demarest, C. S. and Green, C. W. CARRIER SYSTEMS 
ON LONG-DISTANCE TELEPHONE LINES. Bell Sys. Tech. J. 7: 
564-629, 1928.  
Includes mention of the type "C" system, a carrier-suppressed 
single-sideband system.

477. Bailey, Austin, Dean, S. W. and Winthingham, W. T. THE RECEIV-
ING SYSTEM FOR LONG-WAVE TRANSATLANTIC RADIO TELE-
Single sideband, p. 1680-1687.

478. Hartley, R. V. L. U.S. PATENT 1,666,206, MODULATION SYSTEM, 
A method of producing a single-sideband carrier modulated 
wave which compromises generating a modulating frequency band, 
converting said band into two portions which have the same frequency 
characteristics but in which there is between the components of 
the same frequencies occurring in the respective portions, a phase 
difference which is the same for all components, and utilizing such 
portions.

479. Nyquist, H. CERTAIN TOPICS IN TELEGRAPHY TRANSMISSION 
In the case of carrier telegraphy, this discussion includes a 
comparison of single-sideband and double-sideband transmission.

1925

480. Friis, H. T. and Feldman, C. B. A MULTIPLE UNIT STEERABLE 
ANTENNA FOR SHORT-WAVE RECEPTION. Inst. Rádio Engrs. 
Proc. 25:841-917, 1925.  
The experimental system was designed for double-sideband re-
ception, but it is stated that there has recently been completed
equipment which may be substituted for the double-sideband equipment for the reception of reduced carrier single-sideband signals. The new equipment may also be used to select, with crystal filters, one sideband of double-sideband signals.


Describes in detail the equipment and circuit used in the production of the single sideband for transatlantic radiotelephony in the experiments at Rocky Point.


The paper describes the development of a 150-kilowatt (output) radiofrequency amplifier installation built for transatlantic telephone tests. The characteristics of the single-sideband eliminated-carrier method of transmission are discussed with particular reference to its bearing upon the design of the power apparatus.

1923


A review of the series of experiments in 1923 which utilized, for the first time, the single-sideband eliminated-carrier method of transmission.


One of the author's patents which describes single-sideband eliminated-carrier method of transmission.


Several general propositions are stated relative to the signal-to-static ratio, in single- and double-sideband transmission, indicating a majority in practice for the former system.

The effect on the signal of various typical distortions of the radio wave is examined for both single- and double-sideband transmission, as is also that of altering the phase of the locally supplied carrier and of altering its frequency. The resulting distortion of the signal is found, in general, to be more serious for telephony when both sidebands are used and for telegraphy when only one is used.


Reviews the electrical considerations and the experimental work involved in determining the system-design of the radio link. It is stated that many of the known advantages of single-sideband transmission were sacrificed.


Describes a radiotelephony apparatus which economizes in power by sending out only one sideband. The author then gives his arguments in favor of single-sideband transmission.

1922


In the course of the article an explanation is given for achievement of perfect transmission by transmitting only one sideband and suppressing the other.


Cites advantages of single-sideband in long-distance long-wave transmission.

1921


- 89 -
Discussion of single-sideband eliminated-carrier method of transmission, designated type A.
This article is considered a classic on the subject.

1920

U.S. patents 1,343,306 and 1,343,307 describe single-sideband eliminated-carrier method of transmission.
### Author Index

<table>
<thead>
<tr>
<th>Author</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Affel, H. A.</td>
<td>447, 476</td>
</tr>
<tr>
<td>Aiken, C. B.</td>
<td>395</td>
</tr>
<tr>
<td>Albert, A. L.</td>
<td>136, 206</td>
</tr>
<tr>
<td>Allen, J. F.</td>
<td>296</td>
</tr>
<tr>
<td>Almquist, M. L.</td>
<td>415</td>
</tr>
<tr>
<td>Alter, R. S.</td>
<td>140</td>
</tr>
<tr>
<td>Amisima, Toyosi</td>
<td>419</td>
</tr>
<tr>
<td>Angwin, A. S.</td>
<td>335</td>
</tr>
<tr>
<td>Anitov</td>
<td>408</td>
</tr>
<tr>
<td>Arends, J. L.</td>
<td>207</td>
</tr>
<tr>
<td>Arman, L. T.</td>
<td>409</td>
</tr>
<tr>
<td>Arnold, H. D.</td>
<td>483</td>
</tr>
<tr>
<td>Artman, R. G.</td>
<td>222, 223</td>
</tr>
<tr>
<td>Baches, R.</td>
<td>20</td>
</tr>
<tr>
<td>Bailey, Austin</td>
<td>477</td>
</tr>
<tr>
<td>Bakeman, D. C.</td>
<td>208</td>
</tr>
<tr>
<td>Balchin, Z. B.</td>
<td>177</td>
</tr>
<tr>
<td>Bane, C. F.</td>
<td>254</td>
</tr>
<tr>
<td>Barnes, G. W.</td>
<td>62, 83, 148, 271</td>
</tr>
<tr>
<td>Bast, G. H.</td>
<td>63, 336</td>
</tr>
<tr>
<td>Bauer, J. A.</td>
<td>102</td>
</tr>
<tr>
<td>Beale, F. S.</td>
<td>255</td>
</tr>
<tr>
<td>Beanland, C. P.</td>
<td>137, 205</td>
</tr>
<tr>
<td>Bellescize, Henri de.</td>
<td>434</td>
</tr>
<tr>
<td>Benham, W. E.</td>
<td>410</td>
</tr>
<tr>
<td>Berry, F. M.</td>
<td>138, 256</td>
</tr>
<tr>
<td>Black, H. S.</td>
<td>104</td>
</tr>
<tr>
<td>Blackwell, O. B.</td>
<td>491</td>
</tr>
<tr>
<td>Blanchard, R. B.</td>
<td>105, 139</td>
</tr>
<tr>
<td>Bloch, H.</td>
<td>21, 22, 172</td>
</tr>
<tr>
<td>Booth, C. F.</td>
<td>251, 374</td>
</tr>
<tr>
<td>Böttcher, F.</td>
<td>368</td>
</tr>
<tr>
<td>Bourassin, L.</td>
<td>64</td>
</tr>
<tr>
<td>Boveri, T.</td>
<td>23, 65</td>
</tr>
<tr>
<td>Bower, M. M.</td>
<td>209, 411</td>
</tr>
<tr>
<td>Bown, Ralph</td>
<td>412, 426</td>
</tr>
<tr>
<td>Bowser, A. P.</td>
<td>66</td>
</tr>
<tr>
<td>Bradburd, E.</td>
<td>140</td>
</tr>
<tr>
<td>Bradley, R. W.</td>
<td>210</td>
</tr>
<tr>
<td>Bray, W. J.</td>
<td>141, 337, 338, 396</td>
</tr>
<tr>
<td>Brieu, J. J.</td>
<td>67</td>
</tr>
<tr>
<td>Broad, E. R.</td>
<td>178</td>
</tr>
<tr>
<td>Bronzi, G.</td>
<td>68</td>
</tr>
<tr>
<td>Brown, Adamant</td>
<td>24</td>
</tr>
<tr>
<td>Brown, G. H.</td>
<td>375</td>
</tr>
<tr>
<td>Brown, J. N.</td>
<td>1, 25, 69, 106, 124, 203</td>
</tr>
<tr>
<td>Bruene, W. B.</td>
<td>26, 70</td>
</tr>
<tr>
<td>Burch, C. R.</td>
<td>463</td>
</tr>
<tr>
<td>Burns, R. F.</td>
<td>71</td>
</tr>
<tr>
<td>Buschbeck, W.</td>
<td>376</td>
</tr>
<tr>
<td>Byk, M.</td>
<td>72</td>
</tr>
<tr>
<td>Cacheris, John</td>
<td>73</td>
</tr>
<tr>
<td>Carnahan, C. W.</td>
<td>386</td>
</tr>
<tr>
<td>Carson, J. R.</td>
<td>484, 485, 489, 492</td>
</tr>
<tr>
<td>Carter, P. S.</td>
<td>422</td>
</tr>
<tr>
<td>Chakravarti, S. P.</td>
<td>474</td>
</tr>
<tr>
<td>Cheek, R. C.</td>
<td>295, 339, 357, 358, 359</td>
</tr>
<tr>
<td>Cherry, D. D.</td>
<td>199</td>
</tr>
<tr>
<td>Cherry, E. C.</td>
<td>369</td>
</tr>
<tr>
<td>Chesnut, R. W.</td>
<td>447</td>
</tr>
<tr>
<td>Cifuentes, M. G.</td>
<td>134, 142</td>
</tr>
<tr>
<td>Colebrook, F. M.</td>
<td>461</td>
</tr>
<tr>
<td>Colpitts, E. H.</td>
<td>491</td>
</tr>
<tr>
<td>Cork, E. C.</td>
<td>173</td>
</tr>
<tr>
<td>Costas, J. P.</td>
<td>33</td>
</tr>
<tr>
<td>Cridlan, D. E.</td>
<td>178</td>
</tr>
<tr>
<td>Cuccia, C. L.</td>
<td>144</td>
</tr>
<tr>
<td>Curran, L. K.</td>
<td>296, 340</td>
</tr>
<tr>
<td>Dagnall, C. H.</td>
<td>258</td>
</tr>
<tr>
<td>Darlington, Sidney</td>
<td>216</td>
</tr>
<tr>
<td>Dawley, R. L.</td>
<td>297</td>
</tr>
<tr>
<td>Dean, S. W.</td>
<td>477</td>
</tr>
<tr>
<td>Name</td>
<td>Page(s)</td>
</tr>
<tr>
<td>---------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Deane, W. W.</td>
<td>30</td>
</tr>
<tr>
<td>Degawa, Y.</td>
<td>454</td>
</tr>
<tr>
<td>Deloraine, E. M.</td>
<td>462</td>
</tr>
<tr>
<td>Delvaux, J. L.</td>
<td>75</td>
</tr>
<tr>
<td>Demarest, C. S.</td>
<td>476</td>
</tr>
<tr>
<td>Dickieson, A. C.</td>
<td>427</td>
</tr>
<tr>
<td>Dinsdale, A.</td>
<td>298</td>
</tr>
<tr>
<td>Dismore, A. l</td>
<td>145</td>
</tr>
<tr>
<td>Dome, R. B.</td>
<td>353</td>
</tr>
<tr>
<td>Dunnigan, F. A.</td>
<td>109</td>
</tr>
<tr>
<td>Eckersley, P. P.</td>
<td>413, 414, 442</td>
</tr>
<tr>
<td>Eckersley, T. L.</td>
<td>466</td>
</tr>
<tr>
<td>Eckhardt, C. W.</td>
<td>110</td>
</tr>
<tr>
<td>Edmunds, F. E.</td>
<td>217</td>
</tr>
<tr>
<td>Edwards, P. G.</td>
<td>146</td>
</tr>
<tr>
<td>Ehrlich, R. W.</td>
<td>111, 147</td>
</tr>
<tr>
<td>Epstein, D. W.</td>
<td>432</td>
</tr>
<tr>
<td>Erben, J.</td>
<td>272</td>
</tr>
<tr>
<td>Espenchied, Lloyd</td>
<td>488, 489</td>
</tr>
<tr>
<td>Ewen, A. B.</td>
<td>122</td>
</tr>
<tr>
<td>Farkas, F. S.</td>
<td>259</td>
</tr>
<tr>
<td>Feldman, C. B.</td>
<td>480</td>
</tr>
<tr>
<td>Ferguson, E. E.</td>
<td>124</td>
</tr>
<tr>
<td>Fink, D. G.</td>
<td>4</td>
</tr>
<tr>
<td>Fischer, K.</td>
<td>5, 76</td>
</tr>
<tr>
<td>Fisher, H. J.</td>
<td>415</td>
</tr>
<tr>
<td>Fisk, Bert</td>
<td>158, 182</td>
</tr>
<tr>
<td>Floyd, C. F.</td>
<td>178, 341</td>
</tr>
<tr>
<td>Franke, Fritz</td>
<td>32</td>
</tr>
<tr>
<td>Fredendall, G. L.</td>
<td>388</td>
</tr>
<tr>
<td>Friis, H. T.</td>
<td>480</td>
</tr>
<tr>
<td>Fromageot, A.</td>
<td>261</td>
</tr>
<tr>
<td>Gabriel, J. C.</td>
<td>398</td>
</tr>
<tr>
<td>Gecks, F. H.</td>
<td>366</td>
</tr>
<tr>
<td>Genna, W. N.</td>
<td>117</td>
</tr>
<tr>
<td>George, L. L.</td>
<td>183</td>
</tr>
<tr>
<td>George, R. W.</td>
<td>6</td>
</tr>
<tr>
<td>Goedhart, D.</td>
<td>336</td>
</tr>
<tr>
<td>Goldman, Stanford</td>
<td>399</td>
</tr>
<tr>
<td>Goldstine, G. E.</td>
<td>56</td>
</tr>
<tr>
<td>Goodman, Byron</td>
<td>34, 35, 77, 78, 112, 113, 175, 210, 221, 269, 270, 305</td>
</tr>
<tr>
<td>Grammer, George</td>
<td>36, 79, 80, 81, 82, 176, 306</td>
</tr>
<tr>
<td>Green, C. W.</td>
<td>476</td>
</tr>
<tr>
<td>Green, E.</td>
<td>345, 443</td>
</tr>
<tr>
<td>Griese, H. J.</td>
<td>37</td>
</tr>
<tr>
<td>Griffin, D. A.</td>
<td>84</td>
</tr>
<tr>
<td>Grinich, V. H.</td>
<td>196, 200</td>
</tr>
<tr>
<td>Gunter, F. B.</td>
<td>7, 8</td>
</tr>
<tr>
<td>Güttinger, R.</td>
<td>38</td>
</tr>
<tr>
<td>Haberkant, E.</td>
<td>400</td>
</tr>
<tr>
<td>Hahn, W.</td>
<td>377</td>
</tr>
<tr>
<td>Hall, J. R.</td>
<td>39</td>
</tr>
<tr>
<td>Hallenbeck, F. J.</td>
<td>259</td>
</tr>
<tr>
<td>Hamilton, G. E.</td>
<td>222, 223, 307</td>
</tr>
<tr>
<td>Haneman, V. S.</td>
<td>40</td>
</tr>
<tr>
<td>Harbich, H.</td>
<td>448</td>
</tr>
<tr>
<td>Harris, H. C.</td>
<td>179</td>
</tr>
<tr>
<td>Harrison, K. W.</td>
<td>74</td>
</tr>
<tr>
<td>Hartley, R. V. L.</td>
<td>478, 486</td>
</tr>
<tr>
<td>Hayasi, T.</td>
<td>416</td>
</tr>
<tr>
<td>Heising, R. A.</td>
<td>481</td>
</tr>
<tr>
<td>Heller, H.</td>
<td>85</td>
</tr>
<tr>
<td>Hellman, R. K.</td>
<td>417</td>
</tr>
<tr>
<td>Herrmann, J. von</td>
<td>272</td>
</tr>
<tr>
<td>Hill, C. J. W.</td>
<td>455</td>
</tr>
<tr>
<td>Hofer, R.</td>
<td>429, 465</td>
</tr>
<tr>
<td>Hoisington, D. B.</td>
<td>9</td>
</tr>
<tr>
<td>Holahan, James</td>
<td>41</td>
</tr>
<tr>
<td>Holloway, H. R.</td>
<td>179</td>
</tr>
<tr>
<td>Hollywood, J. M.</td>
<td>401</td>
</tr>
<tr>
<td>Holzler, E.</td>
<td>366, 378</td>
</tr>
<tr>
<td>Honey, J. F.</td>
<td>10, 17, 116, 162, 238</td>
</tr>
<tr>
<td>Honnell, M. A.</td>
<td>360</td>
</tr>
<tr>
<td>Hraba, J. B.</td>
<td>42</td>
</tr>
<tr>
<td>Hupert, J. J.</td>
<td>346</td>
</tr>
<tr>
<td>Name</td>
<td>Page Numbers</td>
</tr>
<tr>
<td>---------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Hussey, L. W.</td>
<td>406</td>
</tr>
<tr>
<td>Hutton, Penman, P. R.</td>
<td>409</td>
</tr>
<tr>
<td>Jackson, W. E.</td>
<td>430</td>
</tr>
<tr>
<td>Jacobi, T. E.</td>
<td>308</td>
</tr>
<tr>
<td>Johnstone, D. M.</td>
<td>435</td>
</tr>
<tr>
<td>Jones, T. A.</td>
<td>354</td>
</tr>
<tr>
<td>Kahn, L. R.</td>
<td>149</td>
</tr>
<tr>
<td>Kallman, H. E.</td>
<td>44, 387</td>
</tr>
<tr>
<td>Kamphausen, G.</td>
<td>366</td>
</tr>
<tr>
<td>Kane, J. D.</td>
<td>109</td>
</tr>
<tr>
<td>Kell, R. D.</td>
<td>388</td>
</tr>
<tr>
<td>Kenigsen</td>
<td>408</td>
</tr>
<tr>
<td>Kerwien, A. E.</td>
<td>150</td>
</tr>
<tr>
<td>King, K. C.</td>
<td>74</td>
</tr>
<tr>
<td>King, K. L.</td>
<td>180</td>
</tr>
<tr>
<td>Kirby, H. D. B.</td>
<td>224, 273</td>
</tr>
<tr>
<td>Klass, P. J.</td>
<td>11, 12</td>
</tr>
<tr>
<td>Klenk, L. M.</td>
<td>151</td>
</tr>
<tr>
<td>Koike, Y.</td>
<td>402</td>
</tr>
<tr>
<td>Kolesnikov, M.</td>
<td>456</td>
</tr>
<tr>
<td>Koomans, N.</td>
<td>403, 418</td>
</tr>
<tr>
<td>Kotowski, P.</td>
<td>379</td>
</tr>
<tr>
<td>Kuppfuller, K.</td>
<td>370</td>
</tr>
<tr>
<td>Lacy, W. H.</td>
<td>86</td>
</tr>
<tr>
<td>Ladner, A. W.</td>
<td>466, 471</td>
</tr>
<tr>
<td>Lalande, M. A.</td>
<td>261</td>
</tr>
<tr>
<td>Landon, V. D.</td>
<td>361</td>
</tr>
<tr>
<td>Laport, E. A.</td>
<td>45, 431</td>
</tr>
<tr>
<td>Laver, F. J. M.</td>
<td>46</td>
</tr>
<tr>
<td>Leconte, R. A.</td>
<td>274</td>
</tr>
<tr>
<td>Lenahan, B.</td>
<td>347</td>
</tr>
<tr>
<td>Letheule, P.</td>
<td>467</td>
</tr>
<tr>
<td>Levine, R. H.</td>
<td>24, 47, 161</td>
</tr>
<tr>
<td>Leypold, D.</td>
<td>96, 378</td>
</tr>
<tr>
<td>Lillicrapp, H. G.</td>
<td>337, 338</td>
</tr>
<tr>
<td>Lloyd, W. M.</td>
<td>225</td>
</tr>
<tr>
<td>Loh, W. S.</td>
<td>395</td>
</tr>
<tr>
<td>London, V. D.</td>
<td>361</td>
</tr>
<tr>
<td>Long, R. E.</td>
<td>152, 153, 181</td>
</tr>
<tr>
<td>Lowry, W. R. H.</td>
<td>117, 337, 396</td>
</tr>
<tr>
<td>Loyet, Paul</td>
<td>372</td>
</tr>
<tr>
<td>Lund, N.</td>
<td>154</td>
</tr>
<tr>
<td>Lutsch, A.</td>
<td>275</td>
</tr>
<tr>
<td>MacDiarmid, I.</td>
<td>226</td>
</tr>
<tr>
<td>McFarlane, R. A.</td>
<td>90</td>
</tr>
<tr>
<td>McLaughlin, J. L. A.</td>
<td>48, 227, 309, 348, 380</td>
</tr>
<tr>
<td>Mann, D. O.</td>
<td>276</td>
</tr>
<tr>
<td>Marriner, E. H.</td>
<td>367</td>
</tr>
<tr>
<td>Mason, W. P.</td>
<td>381, 449</td>
</tr>
<tr>
<td>Matsumae, Shigeyoshi</td>
<td>419</td>
</tr>
<tr>
<td>Mattheai, G. L.</td>
<td>246</td>
</tr>
<tr>
<td>May, C. D., Jr.</td>
<td>87, 118</td>
</tr>
<tr>
<td>Meinel, E.</td>
<td>119, 155, 156</td>
</tr>
<tr>
<td>Mellen, G. L.</td>
<td>49</td>
</tr>
<tr>
<td>Merriman, J. H. H.</td>
<td>177</td>
</tr>
<tr>
<td>Mills, R. H.</td>
<td>415, 447</td>
</tr>
<tr>
<td>Mitchell, R. H.</td>
<td>50</td>
</tr>
<tr>
<td>Montfort, L. R.</td>
<td>146</td>
</tr>
<tr>
<td>Morcom, W. J.</td>
<td>88</td>
</tr>
<tr>
<td>Morrison, D. W.</td>
<td>141</td>
</tr>
<tr>
<td>Morrison, H. L.</td>
<td>89</td>
</tr>
<tr>
<td>Morrow, W. E.</td>
<td>49</td>
</tr>
<tr>
<td>Morton, G. A.</td>
<td>394</td>
</tr>
<tr>
<td>Morwood, R. C.</td>
<td>130</td>
</tr>
<tr>
<td>Moses, R. C.</td>
<td>120, 157</td>
</tr>
<tr>
<td>Hüller, H.</td>
<td>38</td>
</tr>
<tr>
<td>Mumford, A. H.</td>
<td>349, 355</td>
</tr>
<tr>
<td>Munn, A. J.</td>
<td>151</td>
</tr>
<tr>
<td>Murphy, F. M. G.</td>
<td>450</td>
</tr>
<tr>
<td>Najork, Jack</td>
<td>310</td>
</tr>
<tr>
<td>Nakal, T.</td>
<td>404</td>
</tr>
<tr>
<td>Nedelka, J.</td>
<td>151</td>
</tr>
<tr>
<td>Nelson, R. T.</td>
<td>3</td>
</tr>
<tr>
<td>Nergaard, L. S.</td>
<td>405</td>
</tr>
<tr>
<td>Newmann, K. L.</td>
<td>45</td>
</tr>
<tr>
<td>Newson, F. W.</td>
<td>99</td>
</tr>
<tr>
<td>Nibbe, G. H.</td>
<td>228</td>
</tr>
<tr>
<td>Nichols, A. H.</td>
<td>311</td>
</tr>
<tr>
<td>Nichols, H. W.</td>
<td>487, 488</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>-----------------------</td>
<td>----------------------</td>
</tr>
<tr>
<td>Norgaard, D. E.</td>
<td>278, 312</td>
</tr>
<tr>
<td></td>
<td>313, 314</td>
</tr>
<tr>
<td>Nowak, E. F.</td>
<td>184</td>
</tr>
<tr>
<td>Nyquist, H.</td>
<td>379, 389</td>
</tr>
<tr>
<td>Oger, E.</td>
<td>91</td>
</tr>
<tr>
<td>Oswald, A. A.</td>
<td>420, 482</td>
</tr>
<tr>
<td>Oswald, J.</td>
<td>159</td>
</tr>
<tr>
<td>Owen, F. C.</td>
<td>122, 338</td>
</tr>
<tr>
<td>Page, H.</td>
<td>455</td>
</tr>
<tr>
<td>Pajgrt, M.</td>
<td>92</td>
</tr>
<tr>
<td>Pappenfus, E. W.</td>
<td>13, 52, 53</td>
</tr>
<tr>
<td>Pembrose, G.</td>
<td>280</td>
</tr>
<tr>
<td>Penick, D. B.</td>
<td>274</td>
</tr>
<tr>
<td>Peterson, E.</td>
<td>406</td>
</tr>
<tr>
<td>Pfleger, K. W.</td>
<td>354, 389</td>
</tr>
<tr>
<td>Plebanski, J. von</td>
<td>453</td>
</tr>
<tr>
<td>Poch, W. J.</td>
<td>432</td>
</tr>
<tr>
<td>Podszeck, H. L.</td>
<td>123</td>
</tr>
<tr>
<td>Polkinghorn, F. A.</td>
<td>315, 390</td>
</tr>
<tr>
<td></td>
<td>444, 445</td>
</tr>
<tr>
<td>Poole, Leonard</td>
<td>124</td>
</tr>
<tr>
<td>Potter, R. K.</td>
<td>472</td>
</tr>
<tr>
<td>Quervain, A. de</td>
<td>54, 55, 185</td>
</tr>
<tr>
<td>Racker, J.</td>
<td>140</td>
</tr>
<tr>
<td>Reeves, A. H.</td>
<td>457, 469</td>
</tr>
<tr>
<td>Reinmeidl, J.</td>
<td>5</td>
</tr>
<tr>
<td>Reinsmith, G. M.</td>
<td>264, 265</td>
</tr>
<tr>
<td></td>
<td>266, 267, 268</td>
</tr>
<tr>
<td>Reque, S. G.</td>
<td>281</td>
</tr>
<tr>
<td>Reynolds, D. K.</td>
<td>162</td>
</tr>
<tr>
<td>Reynolds, F. W.</td>
<td>436</td>
</tr>
<tr>
<td>Rideout, V. C.</td>
<td>94</td>
</tr>
<tr>
<td>Ring, F.</td>
<td>382</td>
</tr>
<tr>
<td>Rhode, S.</td>
<td>356</td>
</tr>
<tr>
<td>Robberson, Elbert</td>
<td>58</td>
</tr>
<tr>
<td>Roberts, Ben</td>
<td>126</td>
</tr>
<tr>
<td>Roberts, W Van B.</td>
<td>127</td>
</tr>
<tr>
<td>Rockaby, F. I.</td>
<td>137</td>
</tr>
<tr>
<td>Rodwin, G.</td>
<td>186, 437</td>
</tr>
<tr>
<td>Roetken, A. A.</td>
<td>421</td>
</tr>
<tr>
<td>Rogers, J.</td>
<td>177</td>
</tr>
<tr>
<td>Rorden, W. L.</td>
<td>167, 195</td>
</tr>
<tr>
<td>Rose, C. F. P.</td>
<td>154, 362</td>
</tr>
<tr>
<td>Rosentreter, E. W.</td>
<td>316</td>
</tr>
<tr>
<td>Rost, G.</td>
<td>379</td>
</tr>
<tr>
<td>Rothe, P. G.</td>
<td>376</td>
</tr>
<tr>
<td>Rounds, P. W.</td>
<td>258</td>
</tr>
<tr>
<td>Russ, Ben</td>
<td>128</td>
</tr>
<tr>
<td>Rust, W. M.</td>
<td>282</td>
</tr>
<tr>
<td>Sachse, H.</td>
<td>383</td>
</tr>
<tr>
<td>Salinger, H.</td>
<td>384</td>
</tr>
<tr>
<td>Schaffstein, G.</td>
<td>433</td>
</tr>
<tr>
<td>Schelleng, J. C.</td>
<td>482</td>
</tr>
<tr>
<td>Scheuch, D. R.</td>
<td>204</td>
</tr>
<tr>
<td>Schlaack, N. F.</td>
<td>160, 187, 444</td>
</tr>
<tr>
<td></td>
<td>445</td>
</tr>
<tr>
<td>Schmid, A.</td>
<td>123, 438</td>
</tr>
<tr>
<td>Schouten, J. F.</td>
<td>63, 336</td>
</tr>
<tr>
<td>Schramm, C. W.</td>
<td>16, 274</td>
</tr>
<tr>
<td>Schreiber, H.</td>
<td>95</td>
</tr>
<tr>
<td>Schultz, L.</td>
<td>115</td>
</tr>
<tr>
<td>Schulz, E.</td>
<td>95</td>
</tr>
<tr>
<td>Senders, J. W.</td>
<td>40</td>
</tr>
<tr>
<td>Sev, A.</td>
<td>283</td>
</tr>
<tr>
<td>Shea, T. E.</td>
<td>475</td>
</tr>
<tr>
<td>Siforov, V. I.</td>
<td>440</td>
</tr>
<tr>
<td>Silver, McMurdo</td>
<td>317</td>
</tr>
<tr>
<td>Simon, J. J.</td>
<td>96</td>
</tr>
<tr>
<td>Singer, C. P.</td>
<td>391</td>
</tr>
<tr>
<td>Skwirzynski, J. K.</td>
<td>129</td>
</tr>
<tr>
<td>Smith, J. E.</td>
<td>422</td>
</tr>
<tr>
<td>Sobotka, H.</td>
<td>379</td>
</tr>
<tr>
<td>Sommerfield, E. H.</td>
<td>97</td>
</tr>
<tr>
<td>Spencer, C. L.</td>
<td>158, 182</td>
</tr>
<tr>
<td>Spencer, R. C.</td>
<td>387</td>
</tr>
<tr>
<td>Stehlik, F. E.</td>
<td>259</td>
</tr>
<tr>
<td>Stevens, A. M.</td>
<td>373</td>
</tr>
<tr>
<td>Stuart, D. M.</td>
<td>430</td>
</tr>
<tr>
<td>Sturgess, H. E.</td>
<td>99</td>
</tr>
<tr>
<td>Sunde, E. D.</td>
<td>103</td>
</tr>
<tr>
<td>Swarm, H. M.</td>
<td>201</td>
</tr>
<tr>
<td>Name</td>
<td>Pages</td>
</tr>
<tr>
<td>-----------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>Talmage, F. E.</td>
<td>102</td>
</tr>
<tr>
<td>Taylor, P. K.</td>
<td>324</td>
</tr>
<tr>
<td>Terman, F. E.</td>
<td>351, 352, 371</td>
</tr>
<tr>
<td>473</td>
<td></td>
</tr>
<tr>
<td>Thomason, R. A.</td>
<td>59</td>
</tr>
<tr>
<td>Thompson, D. L.</td>
<td>327</td>
</tr>
<tr>
<td>Trevor, Bertram</td>
<td>422</td>
</tr>
<tr>
<td>Tschannen, R. F.</td>
<td>60</td>
</tr>
<tr>
<td>Tucker, D. G.</td>
<td>226</td>
</tr>
<tr>
<td>Tuttle, D. W., Jr.</td>
<td>197, 198</td>
</tr>
<tr>
<td>247, 248, 249, 250, 290</td>
<td></td>
</tr>
<tr>
<td>291, 292, 293</td>
<td></td>
</tr>
<tr>
<td>Urtel, R.</td>
<td>407</td>
</tr>
<tr>
<td>Van der Wyck, C. T.</td>
<td>326</td>
</tr>
<tr>
<td>Vesper, W.</td>
<td>76</td>
</tr>
<tr>
<td>Vigoureux, P.</td>
<td>251</td>
</tr>
<tr>
<td>Vilbig, F.</td>
<td>423, 424</td>
</tr>
<tr>
<td>Villard, O. G., Jr.</td>
<td>133, 134</td>
</tr>
<tr>
<td>165, 166, 167, 192, 193, 194</td>
<td></td>
</tr>
<tr>
<td>195, 202, 241, 242, 244, 287</td>
<td></td>
</tr>
<tr>
<td>288, 289, 322, 323, 327, 328</td>
<td></td>
</tr>
<tr>
<td>329, 330, 331, 332, 351</td>
<td></td>
</tr>
<tr>
<td>Vogt, G.</td>
<td>76, 379</td>
</tr>
<tr>
<td>Watkins, E. L.</td>
<td>333</td>
</tr>
<tr>
<td>Weaver, C. E.</td>
<td>203</td>
</tr>
<tr>
<td>Weaver, D. K., Jr.</td>
<td>100, 162</td>
</tr>
<tr>
<td>236, 239, 245</td>
<td></td>
</tr>
<tr>
<td>Webb, B. S.</td>
<td>168</td>
</tr>
<tr>
<td>Weise, D. H.</td>
<td>101</td>
</tr>
<tr>
<td>Werner, H. C.</td>
<td>183</td>
</tr>
<tr>
<td>Westell, E. P. L.</td>
<td>169</td>
</tr>
<tr>
<td>Wheeler, H. A.</td>
<td>385, 392</td>
</tr>
<tr>
<td>Whitby, O. W.</td>
<td>204, 229, 230</td>
</tr>
<tr>
<td>231, 232, 233, 234, 235, 237</td>
<td></td>
</tr>
<tr>
<td>Wier, A. J.</td>
<td>274</td>
</tr>
<tr>
<td>Wilde, G.</td>
<td>466</td>
</tr>
<tr>
<td>Wilson, J. C.</td>
<td>392</td>
</tr>
<tr>
<td>Winthingham, W. T.</td>
<td>477</td>
</tr>
<tr>
<td>Wirkler, W. H.</td>
<td>393</td>
</tr>
<tr>
<td>Wood, J. H.</td>
<td>114</td>
</tr>
<tr>
<td>Wrathall, E. T.</td>
<td>205</td>
</tr>
<tr>
<td>Wright, E. E.</td>
<td>435</td>
</tr>
<tr>
<td>Wright, Howard</td>
<td>135</td>
</tr>
<tr>
<td>Wright, P. N.</td>
<td>170, 171</td>
</tr>
<tr>
<td>Yoneyama, Masao</td>
<td>419</td>
</tr>
<tr>
<td>Young, L. G.</td>
<td>154</td>
</tr>
<tr>
<td>Zeitlenok, G. A.</td>
<td>425</td>
</tr>
<tr>
<td>Zimmerman, Franz</td>
<td>253</td>
</tr>
<tr>
<td>Zworykin, V. K.</td>
<td>394</td>
</tr>
</tbody>
</table>

* * *
Subject Index

<table>
<thead>
<tr>
<th>Term</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adapters</td>
<td>158, 219, 275, 316, 370</td>
</tr>
<tr>
<td>Adjustment</td>
<td>31</td>
</tr>
<tr>
<td>Advantages</td>
<td>11, 15, 41, 49, 52, 148, 184, 189, 280, 320, 422, 490</td>
</tr>
<tr>
<td>Airborne applications</td>
<td>10, 11, 15, 17, 52, 62, 83, 93, 148, 271</td>
</tr>
<tr>
<td>Air-ground communication</td>
<td>41</td>
</tr>
<tr>
<td>Amateur</td>
<td>61, 211, 282</td>
</tr>
<tr>
<td>Amplifiers</td>
<td>31, 72, 80, 154, 161, 212, 220, 362, 409, 482</td>
</tr>
<tr>
<td>See also Linear amplifiers</td>
<td></td>
</tr>
<tr>
<td>AN/ARC 58</td>
<td>12</td>
</tr>
<tr>
<td>AN/FRT-7(XN-1)</td>
<td>183</td>
</tr>
<tr>
<td>Analog devices</td>
<td>40</td>
</tr>
<tr>
<td>Asymmetric sidebands</td>
<td>368, 369, 371, 410, 413, 414, 429, 442, 463</td>
</tr>
<tr>
<td>Asymmetrical sideband</td>
<td>385</td>
</tr>
<tr>
<td>Audio phase-shift</td>
<td>228</td>
</tr>
<tr>
<td>Audio test oscillators</td>
<td>367</td>
</tr>
<tr>
<td>&quot;Automatic&quot; carrier exaltation</td>
<td>130, 132</td>
</tr>
<tr>
<td>Automatic frequency control</td>
<td>207</td>
</tr>
<tr>
<td>&quot;Balancing out&quot; effect</td>
<td>472</td>
</tr>
<tr>
<td>BC-610</td>
<td>50</td>
</tr>
<tr>
<td>Bibliography</td>
<td>46</td>
</tr>
<tr>
<td>Broad-band carrier facilities</td>
<td>274</td>
</tr>
<tr>
<td>Broadcasting stations</td>
<td>18</td>
</tr>
<tr>
<td>Buenos Aires - New York</td>
<td></td>
</tr>
<tr>
<td>link</td>
<td>373</td>
</tr>
<tr>
<td>Cancellation principle</td>
<td>404</td>
</tr>
<tr>
<td>Carrier and sideband</td>
<td>486</td>
</tr>
<tr>
<td>relationship</td>
<td></td>
</tr>
<tr>
<td>Carrier apparatus See Equipment</td>
<td></td>
</tr>
<tr>
<td>Carrier systems</td>
<td>146, 408</td>
</tr>
<tr>
<td>alphabetic designation</td>
<td>411</td>
</tr>
<tr>
<td>Cascade connections</td>
<td>166, 211</td>
</tr>
<tr>
<td>Channel capacity</td>
<td>12, 82, 87, 99</td>
</tr>
<tr>
<td></td>
<td>118, 473</td>
</tr>
<tr>
<td>Circuits</td>
<td>13, 130, 132</td>
</tr>
<tr>
<td>Commercial aspects</td>
<td>1</td>
</tr>
<tr>
<td>Comparison with</td>
<td></td>
</tr>
<tr>
<td>amplitude modulation</td>
<td>17, 116</td>
</tr>
<tr>
<td></td>
<td>120, 121, 339, 357, 358</td>
</tr>
<tr>
<td>asymmetric sideband broadcasting</td>
<td>403</td>
</tr>
<tr>
<td>double sidebands</td>
<td>12, 83, 85</td>
</tr>
<tr>
<td>Compatibility</td>
<td>11, 43</td>
</tr>
<tr>
<td>Constant phase differences</td>
<td>216, 245</td>
</tr>
<tr>
<td>Converters</td>
<td>51, 109, 115, 319</td>
</tr>
<tr>
<td>Cross-talk attenuation</td>
<td>21</td>
</tr>
<tr>
<td>Crystals</td>
<td>59, 217, 374, 449</td>
</tr>
<tr>
<td>Cutoff</td>
<td>402</td>
</tr>
<tr>
<td>CV-216/URR</td>
<td>51</td>
</tr>
<tr>
<td>Delay equalization</td>
<td>258</td>
</tr>
<tr>
<td>Demodulation</td>
<td>94</td>
</tr>
<tr>
<td>Design</td>
<td>2, 13, 100</td>
</tr>
<tr>
<td>Detectors</td>
<td>133, 327</td>
</tr>
<tr>
<td>Development</td>
<td>98</td>
</tr>
<tr>
<td>Disadvantages</td>
<td>320, 422</td>
</tr>
<tr>
<td>Distortion</td>
<td>21, 44, 70, 81, 91</td>
</tr>
<tr>
<td>Drift prevention</td>
<td>152</td>
</tr>
<tr>
<td>Doppler</td>
<td>114</td>
</tr>
<tr>
<td>Electrical fundamentals</td>
<td>136</td>
</tr>
<tr>
<td>Elements</td>
<td>86</td>
</tr>
<tr>
<td>Engineering details</td>
<td>32</td>
</tr>
<tr>
<td>Envelope elimination</td>
<td>149</td>
</tr>
<tr>
<td>Equipment</td>
<td>10, 20, 22, 23, 27, 32</td>
</tr>
<tr>
<td></td>
<td>38, 55, 65, 72, 75, 150, 162, 172</td>
</tr>
<tr>
<td></td>
<td>174, 285, 286, 296, 326, 337, 355</td>
</tr>
<tr>
<td></td>
<td>364, 365, 383, 447, 464, 480</td>
</tr>
</tbody>
</table>

- 96 -
Evaluation 121, 183
Exalted carriers 143, 151
Exciters 9, 25, 78, 89, 96, 168
203, 210, 217, 262, 269, 270
276, 278, 282, 295, 297, 367

Fading machines 338
Ferrites 73
Filters 61, 173, 245, 256, 259
261, 276, 375, 449
coopial 384
Collins 9
crystal 71, 168, 176, 203, 217
324, 341
design 140
dual-crystal 89
electromechanical 6, 57
mechanical 9, 126, 127
quartz 381
shape factor 392
theory 401
toroid 25
vestigial sideband 37
Filtration problems 226
Frequency analysis 461

Generators 3, 60, 162, 170, 179
240, 312, 333, 334, 347
351, 360
Goniometers 90
Ground-to-air 343, 344

Handbooks 14, 19, 51, 371
Heterodyne rejection circuit 380

In Pakistan 125
Internship 209

Lenkurt 66
LD-RI 186
LD-T2 187, 252

Linear amplifiers 7, 8, 26, 50
80, 110, 128, 147, 149, 175
181, 199, 281, 345

See also Amplifiers
Long-range 49, 107, 108, 116, 117
158, 160, 182, 218, 262, 263, 264
265, 266, 267, 268, 299, 300, 301
302, 303, 304, 342, 343, 349

McLaughlin principle 34
Magnetic tape 40
Mettlen Load Distributing Centre 54
Military 11, 16, 29, 47, 87
334, 335
Mobile 24, 124, 271
Modification 97, 153
Modulation 21, 46, 49, 104, 224
227, 288, 289, 322, 323, 350, 358
363, 416, 424, 425, 431, 433
452, 453, 458, 478, 489, 551
Modulators 61, 68, 73, 113, 138
216, 333, 406, 417, 438, 454
Multiplexing 46, 49, 66, 361

Negative feedback 91
Netherlands link 418
Noise susceptibility 21
Noise voltages 169
Non-linear types 56

100-KC carrier 57
Operating tests 332
Operation 120, 122
Operational experience 255
Oscillation rectification 277

Paris demonstration 468, 469

Patents 393, 443, 478, 484, 492
Performance improvement 111
Phase

displacement 423

- 97 -
<table>
<thead>
<tr>
<th>Topic</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>distort</td>
<td>5, 33, 145, 157, 197</td>
</tr>
<tr>
<td>equaliz</td>
<td>3, 260, 283, 309, 313, 331</td>
</tr>
<tr>
<td>modula</td>
<td>355, 394, 396, 397, 398</td>
</tr>
<tr>
<td>rotatio</td>
<td>36</td>
</tr>
<tr>
<td>Phase-sh.</td>
<td>58</td>
</tr>
<tr>
<td>Phasing method</td>
<td>36</td>
</tr>
<tr>
<td>princ.</td>
<td>330</td>
</tr>
<tr>
<td>Phone sig</td>
<td>161</td>
</tr>
<tr>
<td>Planning</td>
<td>162</td>
</tr>
<tr>
<td>Polyphase</td>
<td>298, 310</td>
</tr>
<tr>
<td>Polyphase</td>
<td>90, 131</td>
</tr>
<tr>
<td>Polyphase</td>
<td>284, 487</td>
</tr>
<tr>
<td>Power</td>
<td>141</td>
</tr>
<tr>
<td>efficie</td>
<td>424</td>
</tr>
<tr>
<td>gain</td>
<td>221</td>
</tr>
<tr>
<td>lines</td>
<td>144, 352</td>
</tr>
<tr>
<td>output</td>
<td>100, 201, 202</td>
</tr>
<tr>
<td>Preamplifier</td>
<td>171, 174, 213, 214</td>
</tr>
<tr>
<td>Procedure</td>
<td>77</td>
</tr>
<tr>
<td>Radiation</td>
<td>463</td>
</tr>
<tr>
<td>Receivers</td>
<td>480</td>
</tr>
<tr>
<td>airborne</td>
<td>15</td>
</tr>
<tr>
<td>design</td>
<td>42</td>
</tr>
<tr>
<td>diversity</td>
<td>159</td>
</tr>
<tr>
<td>HF</td>
<td>33</td>
</tr>
<tr>
<td>heterodyne-eliminating</td>
<td>171, 174, 213, 214</td>
</tr>
<tr>
<td>KW2/6</td>
<td>437, 455, 477</td>
</tr>
<tr>
<td>Marconl</td>
<td>340, 341, 352, 355, 374, 421</td>
</tr>
<tr>
<td>mobile</td>
<td>284, 487</td>
</tr>
<tr>
<td>Musa</td>
<td>13</td>
</tr>
<tr>
<td>Navy AR-88</td>
<td>143</td>
</tr>
<tr>
<td>Siemens</td>
<td>12</td>
</tr>
<tr>
<td>splatter</td>
<td>95</td>
</tr>
<tr>
<td>synchronous detection</td>
<td>95</td>
</tr>
<tr>
<td>TH864</td>
<td>35</td>
</tr>
<tr>
<td>Receiving components</td>
<td>33</td>
</tr>
<tr>
<td>performance evaluation</td>
<td>72</td>
</tr>
</tbody>
</table>

**Strategy**
- Collins Radio Co. 28, 29
- low-power 45

**Techniques**
- 11, 53, 69, 131, 132
- 133, 135, 136, 139, 141, 163, 164
- 189, 190, 191, 192, 193, 194, 197
- 198, 208, 229, 230, 231, 232
- 239, 242, 243, 244, 247, 248
- 249, 250, 257, 287, 290, 291
- 292, 293, 305

**Telegraphy**
- 76, 141, 308, 374
- 422, 479, 486, 491
Telephony . 16, 45, 63, 74, 76, 92
119, 135, 141, 155, 156, 160, 176
177, 272, 273, 284, 305, 314, 315
336, 353, 356, 362, 373, 377
378, 390, 400, 411, 412, 415, 418
420, 421, 426, 427, 428, 430
440, 444, 445, 455, 456, 457
459, 465, 467, 468, 469, 470
474, 476, 477, 482, 483, 485
486, 487, 488, 491
Telephotograph . . . . 436
Television 37, 44, 64, 101, 102
173, 223, 382, 384, 386, 387
388, 394, 399, 401, 405
407, 432
Terms used . . . . . . 11
Tetrodes . . . . . . 318, 325
Tokyo and Kagosima link . 419
Transient response . . . . 391
Transition . . . . . . 10
Transceiver . . . . . . 12
Transmission 77, 82, 222, 362
363, 366, 369, 370, 371, 386
388, 389, 394, 395, 396, 399
402, 442, 448, 450, 475, 479

Transmitters . 27, 33, 50, 56, 67
72, 88, 150, 151, 154, 155, 156
180, 187, 203, 204, 218, 253
280, 297, 307, 311, 328, 330
337, 345, 346, 376, 379
Transoceanic 151, 377, 378, 362
383, 420, 426, 445, 455, 459
460, 462, 477, 481, 483, 488
Traps . . . . . . . . 38
Trends . . . . . . . . 107
Tubes . . . . . . . . . 31
Tuning . . . . 105, 130, 168, 221
Types . . . . . . . . 11
Unequal fading . . . . 466, 471
Vestigial sidebands . . . . 37, 64, 101
103, 129, 140, 173
375, 384
Waveform distortion . . . . 200
YRS-1 . . . . . . . . 145

* * *

- 99 -