Early History of Single-Sideband Transmission*

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Summary—This paper briefly reviews wire and radio art at the
time of the invention of the single-sideband method of transmission.
Recognition of sidebands, realization that either sideband contains
the entire information and that the carrier wave conveys none, and
the experimental discovery of homodyne reception, all preceded
the invention.

The method was first employed commercially in carrier telephone
systems.

Narrow resonance characteristics and limited transmitting power
necessitated elimination of one sideband and carrier in the first
transoceanic radio telephone system.

Successful application to hf radio systems and superior perform-
ance under fading conditions resulted in general adoption of single
sideband for long-haul services.

The SINGLE-SIDEBAND METHOD of trans-
mision was conceived in the mind of John R.
Carson in 1915 through pure analysis resulting
from his mathematical studies related to modulation
of a continuous-wave carrier by means of thermionic
vacuum tubes.1 Almost simultaneously, H. D. Arnold
realized the possibility in connection with tests of the
Arlington experimental radio telephone transmitter
of that year. Like situations preceding some other great
contributions to telephone communication, in this
instance the high frequency wire and radio art was ripe
for the invention.2

The first step was the recognition of sidebands per se.
Until well after Carson’s invention, there seems to have
been no general, clear-cut recognition outside the Bell
System, that modulation of a carrier by voice waves
results in side frequencies above and below the carrier.
LeBlanc, in describing his multiplex system,3 speaks of
the modified high-frequency wave and calls for a chan-
nel spacing “high compared with the pitch of the sound
waves.” This might be construed as implying that a
transmission band is involved but LeBlanc makes no
comments in this direction. Fleming4 treats the modu-
lated carrier as a wave of constant frequency but vary-
ing amplitude. Stone5 as late as 1912 says, “There is, in
fact, in the transmission of a given message, (by carrier)
but a single frequency of current involved.”

The combining of two waves in a nonlinear element
to produce sum and difference waves was an old phe-
nomenon in acoustical physics. There appears to have
been a certain carryover of that knowledge to the case

of electric-wave modulation by both Campbell and
Colpitts whereby sidebands were tacitly assumed to
exist although admittedly not very concretely visual-
ized. The band spectrum of voice waves was well known.
Campbell’s electric wave filter6 had been invented. It is
clear from correspondence that by 1913 Bell System
engineers were assuming that speech, in being trans-
lated upward in frequency by modulation on a carrier,
would still constitute a band of frequencies.

In the summer of 1914 a young physicist who was
working on radio, in familiarizing himself with the sub-
ject, worked out a simple trigonometric analysis of an
amplitude-modulated wave in his notebook. It showed
three distinct components, the carrier and the upper
and lower waves set off therefrom by the modulating fre-
quency. The youthful analyst was Carl R. Englund; his
notebook was dated August 19, 1914. Others may have
done the same but this is the earliest known record.
Nothing seems to have come directly from it. Those who
knew apparently did not grasp the entire significance.

In October, 1914, R. A. Heising set up and tested a
vacuum tube transmitting and receiving terminal, over
an artificial line in the laboratory, which simulated two
carrier telephone channels. This was the first putting
together of an all-vacuum tube, high-frequency tele-
phone sys’em.1: used separation coupled tuned circuits
for frequency. Heising’s report, dated December 18,
1914, recognized sidebands and mentioned the filter for
realizing a “flat-topped transmission band.”

The full blown appreciation came in mid-1915 during
the radio-telephone experiments conducted at the U. S.
Navy Radio Station at Arlington, Va. H. D. Arnold
suggested that the antenna at Arlington be tuned to one
side of the carrier frequency in order to pass one-side-
band well, even though the other was attenuated. Here
was recognition that one sideband contained all the sig-
nal elements necessary to reproduce the original speech.
During this same period, John R. Carson independently
set about analyzing vacuum-tube modulation, found
the discrete components and recognized that one side-
band and the carrier need not be transmitted. Kendall7
had just discovered that injection of a carrier at the re-
ceiver greatly enhanced detection. Carson knew of these
homodyne experiments and, since they demonstrated
the feasibility of reintroducing the carrier at the receiv-
ing end, they may have promoted his idea of eliminating
the carrier at the transmitter. At any rate, Carson in
addition to suppressing one sideband, did propose sup-
pression of the carrier as well: a step beyond Arnold’s

* Original manuscript received by the IRE, August 21, 1956.
† Retired from Bell Telephone Labs., New York, N. Y., 1956.
2 E. H. Colpitts and O. B. Blackwell, "Carrier current telephony
3 M. LeBlanc; U. S. Patent 857,079; 1907.
4 J. A. Fleming, "Electric Wave Telegraphy and Telephony,"
5 J. S. Stone, "The practical aspects of the propagation of high-
frequency electric waves among wires," J. Franklin Inst., vol. 174,
p. 353; October, 1912.

6 G. A. Campbell, U. S. Patent 1,227,113 and 1,227,114; 1917.
7 B. W. Kendall, U. S. Patent 1,330,471.
After several patent interferences Carson was granted in U. S. Patent 1,449,382, filed in 1915, claims both to suppression of one sideband and to suppression of the carrier with or without suppression of one sideband. (See Fig. 1.)

The invention of the copper-to-glass seal by Housekeeper brought rapid development of water-cooled thermionic vacuum tubes following World War I. This opened the possibility of early realization of the Bell System's long quest for a transoceanic telephone service. During 1922 a powerful experimental single-sideband transmitter, operating at a midband frequency of 57 kc, was set up by their research engineers at Rocky Point, Long Island. (See Figs. 2 and 3, on the next page.) A receiving station was established at New South Gate, near London, England. Reliable one-way speech transmission was publicly demonstrated over this system in January, 1923. Thereafter the British Post Office worked hand-in-hand in establishing the first New York-London circuit which was opened for service in January, 1927. The limited transmitting power capacity and the narrow-resonance bands of efficient antennas at the low frequencies employed in this system, made imperative the adoption of single-sideband suppressed carrier methods. However, the frequencies were about three times higher than those used in existing carrier telephone systems. Hence, both the sideband generators and the power amplifiers involved pioneer development.

The first overseas system was followed in the next few years by so-called short-wave systems operating in the range now designated as high frequency (3-30 mc). Until about 1936 all the short-wave systems transmitted double sideband and carrier because the art in this frequency range did not permit practical single-sideband operation. However, the Bell System and British Post Office transmitters and possibly others were designed with low-level signal generators and power amplifiers so that the generators could be replaced by single-sideband generators when available.

In the late 1920's the Bell Telephone Laboratories constructed a special receiver with which to investigate the characteristics of shortwave single-sideband reception. This receiver occupied seven bays and used crystal filters. It was capable of receiving double-sideband transmissions and separating the sidebands and the carrier for experimental purposes. Provision was made for isolating, reconditioning, and re-inserting the transmitted carrier. Locally generated carrier and automatic frequency control were also provided, so that

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8 B. W. Kendall, "Carrier-current telephone systems," Bell Labs. Rept., vol. 1, pp. 154-159; December, 1925.


it was possible to simulate almost any kind of reception. The observations made with this equipment brought decisions to develop shortwave single-sideband transmitting and receiving units for a transoceanic trial.\textsuperscript{13,14} Upon completion, the transmitter was taken to England and with the cooperation of the British Post Office, set up in the station at Rugby. There followed extensive tests which confirmed that the theoretical advantages could be achieved in practice, in the presence of multiple path transmission. This trial equipment was placed in commercial operation; in 1936 designs for production were initiated.\textsuperscript{15–18} During the next decade about 50 single-sideband circuits were established in all parts of the world using units of these designs; the applications increased thereafter.

During World War II single-sideband systems did valuable service in providing connections between continental United States and the armed forces in various parts of the globe. Many of these were multichannel teletypewriter systems using telephone circuits with speech channels used only for special purposes. The telegraph signal was two-tone (mark and space) with frequency diversity (4 tones per telegraph channel). After the war improved single-sideband equipments were developed in the Bell Telephone Laboratories and by several other companies in the United States and abroad. Today the single-sideband method is rather generally recognized as standard for long-haul point-to-point transmissions and is being seriously considered for other purposes such as communication with aircraft.\textsuperscript{19} Recently the Federal Communications Commission has proposed rules requiring single sideband for all point-to-point radio telephone transmission below 30 megacycles.

The first short-wave single-sideband equipment provided only a single speech channel on one side of the carrier, but it was quickly determined that a common power amplifier could be made sufficiently linear to permit adding a second channel on the opposite side of the carrier. At first, better performance was secured by spreading one channel from the carrier so that unwanted distortion products generated in the power amplifier by one channel would fall in the space between active bands and thus not create noise in the other channel. The urgent need for more telephone channels during the war years resulted in spreading both normal speech bands away from the carrier. A third circuit was then secured by splitting a speech channel and fitting the parts into the narrow-frequency space available adjacent to and on both sides of the carrier.

A single-sideband signal is generated by one of two basic methods: 1) modulating a carrier with a baseband signal and then suppressing all but one sideband with filters; or 2) balancing out the carrier and one sideband by an arrangement of double modulators in which the carrier and modulating signal applied to one modulator are shifted 90° with respect to those applied to the other modulator. The filtering method easily provides greater

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suppression and operating stability. The basic idea of the balancing scheme was invented by Hartley.\textsuperscript{29} A scheme for transmitting independent intelligence on the two sides of the carrier is shown in a patent issued to Potter.\textsuperscript{31} Green\textsuperscript{22} suggested use of balancing methods for separating the two sidebands at the receiver. Balancing has been used in some short-haul carrier telephone systems where high suppression is not essential. In recent years balancing methods have received considerable attention in a number of laboratories as the search proceeds for economical ways to make various new single-sideband applications.

Once the feasibility of single-sideband transmission had been demonstrated, the Bell System was not alone in appreciating its advantages. The British Post Office supported a continuous program of development to establish improved systems. The Dutch, pioneer workers in the field, developed equipment and established multiplex circuits between the Netherlands and the Netherlands East Indies.\textsuperscript{23} Reeves\textsuperscript{24} of International Standard Electric Corporation did some major pioneer work. This paper makes no attempt to cover the expanded activity in the single-sideband field since World War II.

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**Bibliography**


