

the development of Amateur SSB: a brief history

70 years of progress
marks this familiar mode

Single-sideband radio telephone transmission in the Amateur bands — even well into the VHF region — is taken for granted these days. But it wasn't always so. Many Amateurs remember the days when amplitude modulation with full carrier (AM) reigned supreme. (For some it still does — **Editor.**)

While the era of Amateur SSB is generally considered to have begun with an article published in 1948 by Arthur Nichols¹, much work was done well before; basic groundwork, in both theory and in hardware, was completed as early as 1933 by the ARRL and other groups. Unfortunately, much of this work was considered too complex for the Amateur community, and was consequently not published.

early history

The earliest written analysis of an amplitude modulated signal consisting of a carrier and upper and lower sidebands separated by the modulating frequency was made by Carl R. Englund, in a paper dated August 19, 1914.² Englund who worked for the Bell System, recorded his analysis in his engineering notebook, but no record of what — if any — use was made of this information survives today. There is evidence that others were aware of the existence of sidebands, but Englund's analysis is apparently the earliest record to survive. In 1915, for example, H.D. Oliver, a telephone company engineer working transatlantic radio telephone at NAA, the then-new Navy radio station at Arlington, Virginia, considered the use of SSB for solving the problem of communications. Oliver proposed to tune the antenna to eliminate the carrier and one sideband, which would have been entirely practical because the transatlantic tests were

made at 5000 meters (60 kHz), where antenna *Q*s are necessarily very high. But because the tests were carried out using AM, nothing appears to have come of this idea.

The fact that SSB, with or without a carrier, was considered as a means of transmitting information implies not only knowledge of the existence of sidebands, but also of the fact that information is contained therein.

No attempt was made to develop SSB for radio communication purposes at this time, probably because of the complexity of the receiver that would be required. State-of-the-art receivers in those days consisted of several stages of RF amplification — a detector followed by several stages of audio amplification. Likewise, filter design, too, was primitive by today's standards.

first SSB transmitted on a wire

The only organization to demonstrate interest in SSB was the Bell System, which developed the technique for long distance wire-line telephony. The first commercial wire carrier system using SSB was placed in service in 1918. SSB techniques were used exclusively for long distance telephone circuits until relatively recently, when they were replaced by pulse-code modulation (PCM).

The first application of SSB to radio was made in 1922, again by the Bell System. Bell set up an SSB transmitter, operating on 57 kHz, at Rocky Point, Long Island, and the British Post Office established a receiving station at New South Gate, England, near London. One-way communication was established in January 1923, proving the feasibility of SSB for transatlantic communication. The return message from England came by transatlantic telegraph cable. When a transatlantic radio telephone circuit was put into commercial operation on long wave (57 kHz) in 1927, SSB was used. As the traffic increased and additional channels were needed, these were operated in the

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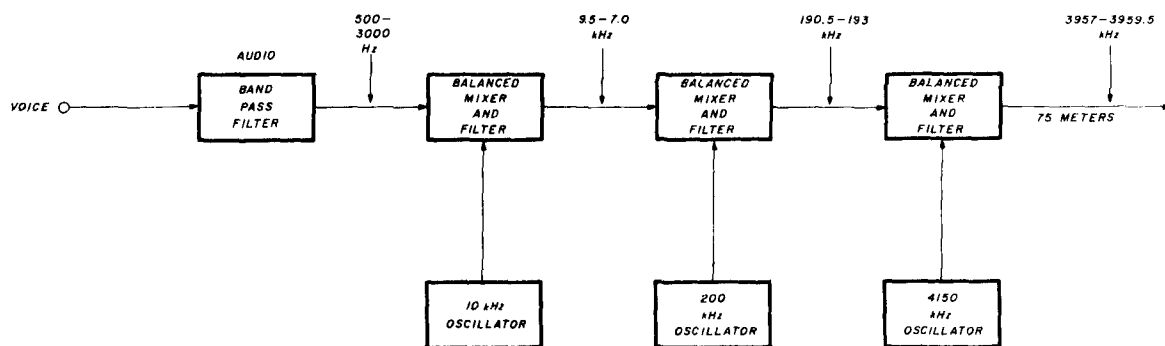


fig. 1. Block diagram of 75-meter SSB transmitter developed by Robert Moore circa 1933.

short-wave band (HF, in today's terminology). Interestingly, short-wave circuits used AM because SSB techniques for HF were not perfected until 1936.

amateur SSB

As has often been the case in the history of Amateur Radio, one or two hams or rather groups of hams developed techniques for Amateur communications that closely paralleled work going on in industry. In the early 1930's, while Bell was adapting the SSB techniques used on wire-line to HF radio for transatlantic telephone circuits, two Amateur groups were working on Amateur SSB.

The first record of the development of an SSB transmitter for Amateur use that I have been able to find appeared in a series of three articles by Robert M. Moore, then W6DEI, in a magazine called *R/9*; a block diagram of Moore's transmitter is shown in fig. 1.³ (Old-timers will remember *R/9* as a first-rate technical magazine. In fact, one of the issues describing Moore's SSB transmitter also features an article on how to build a parabolic antenna — interesting reading even today! The name *R/9* was lost when the monthly publication merged with *Radio* in January, 1936, after which *Radio* itself became a first-rate technical magazine.) Moore acknowledges having drawn on the published data of the Bell System "for a portion of the material used" in his series.

The second group working on SSB was an ARRL team led by James J. Lamb, then Technical Editor of *QST*. At the Board of Directors' meeting held on May 12, 1933, Bernard J. Fuld, W2BEG, director of the Hudson Division, moved:

"That the technical staff of QST is instructed to investigate the feasibility, and, if feasible, is instructed to undertake the development at reasonable prices, of apparatus and methods of single-sideband and carrierless 'phone transmission'."

The motion passed unanimously.⁴

As a result of this motion, K.B. Warner, W1EH, who was secretary of the League as well as Editor-in-Chief and Business Manager of *QST*, sent a memorandum to James Lamb; because of its historical interest and the insight it provides into the personalities of the people involved, it is reproduced in fig. 2.

The memorandum was followed by a short ARRL inter-office memo (fig. 3) adding directional antennas to SSB and encouraging a "serious attempt to accomplish something." The list of names at the top of the memo is worth reviewing; how many of these people can you remember?

Lamb and his associates did go into a huddle, as requested; Lamb wrote a 12-page report, which he forwarded to Warner on September 25, 1933. While the report is too long to reproduce here, an excerpt (fig. 4) is included because A.L. Budlong (then ARRL Communications Manager) wrote some comments on this part of Lamb's report. Fig. 5 shows Budlong's comments on Lamb's SSB report.

Although Lamb's report was never published in *QST* as originally written, a later, revised version was published in the October, 1935 *QST*.⁵ This article was not listed in either the table of contents for that issue or in the annual index published in the December 1935 *QST*.

The decision of ARRL management not to pursue development of SSB as a means of reducing phone band interference was apparently based on the assumption that SSB equipment was too complicated for the average Amateur in 1933-34.

At that time, it was the policy of League officials, as well as the *QST* editorial staff, to do everything possible to encourage more people to become licensed Amateurs. This was believed necessary for the preservation of Amateur frequency allocations in the short-wave bands that were (and still are) essential for its continuation. In 1933-34 there were only about 20,000 licensed Amateurs — a small force in comparison to the highly organized, well-funded

JJL:

By vote of the Board of instructors, we are instructed to investigate the feasibility of applying to amateur operation single-side-band and carrierless phone transmission, and if we find it feasible we are further instructed to produce cheapest-possible apparatus to accomplish it.

I now place this matter in your hands. Suggest you and your cohorts do a bit of reading up on it and then go into a huddle. I shall then need a written report of what you find and what you propose to do about it. I believe that that report will either state that there is ND and give definite reasons why not, or will find ND except in a limited extent in which you propose certain investigation and further report, or (theoretically at least) will find that there is good possibility of accomplishing something and that lab work is going to be undertaken along such-and-such lines, with a further report to come.

It is my instant impression that there is ND. I think that that will be the offhand opinion of all of you. I ask you-all, however, to put on your amateur thinking-caps and look at this from the traditional amateur point of view that there is always a new way to skin a cat. Without any doubt at all any such development would be of tremendous importance -- as an amateur achievement, as a commercial development of vast worth, as an immense practical aid in congested amateur phone territory. To be acceptable, your report will have to show to the Board why it is not practicable to build such amateur phone stations, e.g., because it would have to have a filter that cannot be produced for less than \$3000.

I do not know whether an autodyne receiver is capable of supplying the carrier for suppressed-carrier transmission or not. If it is not, and if it is not possible to use any local oscillator easily to supply the missing carrier, I should think that method of small interest to us.

I also wish to suggest your consideration of partial-sideband ~~xxxxxx~~ suppression if you do not find it practicable to attempt full suppression of one sideband. I mean, a method using a filter so as to cut off all frequencies above the value necessary for reasonably good speech, thus suppression unnecessarily high voice frequencies, harmonics, etc. I believe that a filter to do that can be built for a very small fraction of the cost of one necessary for eliminating one sideband neatly.

.....

At this stage in my note-writing you and Hebie have used up my remaining time but I have just discovered that I have, compact in one booklet, all the studies made of this thing by the CCIR and I am going to conclude by handing you this publication of Opinions, calling your attention to pp. 59 to 74 relating to this subject. The booklet is to be returned to me, please.

HW?



KBW 6/6/33

PS - Her reports, of course, are to be transmitted by me to the Board

fig. 2. K.B. Warner, League secretary and Editor-in-Chief and Business Manager of QST, sent this memo to QST Technical Editor James Lamb.

American Radio Relay League
OFFICE MEMO

Beaudin	Hebert	Mr. Maxim
Reekley	Houghton	Mr. Stewart
Budlong	Houldson	Mr. Segal
Chamberlain	Hull	
De Soto	Lamb	
Grammer	Radimon	
Handy	Scanlan	Mr. _____

Please note and return to me.
Returned noted; thanks.
Referred to you for necessary action.
For your files.
Please give me information on marked portion.
Please note and file.
What do you think about it?
For your information.
When finished with your part, please pass on to _____

I have just discovered that it was Fuld's intention to include in that motion re sideband suppression, etc., the subject of directional antennas. That is a separate and large order, but one that you might take a look at in your conference.

I concluded my note of yesterday without saying (as I meant to, that I want you fellows to make a serious attempt to accomplish something along the desired lines if it is feasible.

fig. 3. Brief inter-office memo urged League staffers to make a "serious attempt to accomplish something."

entrepreneurs and industrialists representing commercial communications and international broadcasting, who wanted to take over the Amateur frequency assignments for their own use.

The League felt that the best way to increase the number of licensed operators was to describe equipment that was "sure-fire" in all League publications; that is, equipment that was easy to build with simple hand tools and certain to work without elaborate test equipment or much experience on the part of the builder. There was concern that if a newcomer started out in Amateur Radio by building the latest equipment — an SSB rig for example — he would probably be unable to make it work, and would become discouraged and leave Amateur Radio.

Because Amateur Radio is flourishing today, we can only speculate about what the outcome might have been if the Amateur community had actively pursued SSB in the early 1930s. If the Bell System, with all its resources, which were substantial even then, was not able to develop practical SSB equipment for HF radio until 1936, it seems likely that it would have been all but impossible for individual Amateurs to have done it in 1933 or 1934. (Even today, most Amateurs prefer to buy, rather than build, their SSB equipment.)

The League did stick to their "keep it simple" philosophy, despite the frustration of some technical people at ARRL headquarters who would have preferred to have been able to continue their pioneering developmental work in Amateur SSB for professional reasons.

Even though the ARRL did not pursue the develop-

-3-

The first of these, suppressed-carrier double-side-band transmission, would eliminate the steady-type interference resulting from the heterodyning of undesired carriers with the ~~and would reduce distortion from selective fading~~ carrier of a desired station, but would require the same frequency band-width as would normal (carrier and double-side-band) transmission. Simple suppressed-carrier transmission also might have an economic advantage in that the full capability of a linear r.f. stage could be utilized for the intelligence-carrying side-band power to the exclusion of the carrier power that normally is transmitted. In a 100% sinusoidally modulated wave, 2/3 of the total power is represented by the carrier and 1/3 by the side-bands. ^{2,3} For instance, whereas a truly linear amplifier of 300-watt maximum capability would have but 100-watt side-band output with a normal 100% modulated wave, with the carrier suppressed the side-band power with the same amplifier theoretically could be as high as 300 watts, representing three times the intelligence-carrying power of the carrier-and-double-side-band capability. From the amateur point of view this advantage is more apparent than real, however, because a given r.f. amplifier when operating Class-B and ~~handling~~ handling only side-band power has negligible advantage in side-band output over the same amplifier when operating Class-C with plate modulation in the system of carrier-and-double-side-band transmission generally used by amateurs. ~~According to the simple suppressed-carrier system that would be used in the receiving end, the carrier and one side-band would be transmitted, and the other side-band suppressed, is technically less feasible than~~

-4-

suppression of the carrier and elimination of one side-band because elimination of one side band without affecting the carrier would be more difficult than suppression of the carrier with elimination of one side-band. This system hardly merits consideration. Although it would seem to offer advantages in that the frequency band required would be lessened by the one set of side-band components eliminated, it would offer no opportunity of realizing greater intelligence-carrying output from a transmitter of given peak-power rating than is obtained with carrier and double-side-band transmission. The gain would be negligible in view of the additional technical complexities involved. The heterodyne interference problem would be in no wise lessened. ^{The third system,} ~~As shown in type mentioned,~~ single-side-band transmission with the carrier suppressed, appears to be not only the most economical in frequency-band requirement and in utilization of transmitter capability, but also to hold less technical complication in reception than the first-mentioned type (double-side-band), and still less technical complication in transmission than ^{it also eliminates most of the distortion from selective fading} the second type (carrier and one side-band). The present objective must be primarily the minimizing of the interference problem, so far as that may be possible, to the end that ^{greater} utilization of the available amateur 'phone bands may be hoped for. Hence, only single-side-band suppressed-carrier transmission warrants our serious consideration. This view is reinforced by the receiving considerations to be discussed later.

Carrier Suppression

Two means of suppressing the carrier-frequency component are possible. One would be a filter having sharp attenuation at the carrier frequency and passing either one set or both sets

fig. 4. Excerpt from Lamb's 12-page report, sent to Warner on September 25, 1933.

Bottom p.3, top p.4. I do not agree. The sole aim of Board's hope is to increase effective width of fone bands by changing amateur radio to a svstem that requires fewer kc for a transmitter. ~~Jim~~ Jim departs from the point when he damns this system by saying it offers no opportunity to increase output from given tubes. Nobody cares. Nobody cares even if output is decreased -- if stations now occupy only half as much room.

Considering difficulty of replacing carrier, and of tuning at receiver with suppressed-carrier method, I hardly can embrace it. I am most reluctant to accept Jim's top of page 4 that it is too difficult to suppress just one ~~sideband~~. He there makes bold statements with no supporting references. His language looks more like prejudice than logic that the reader embraces because it is self-warranting.

At this moment I've read only first 3½ pages, but I here make note that I'm pretty sure that the only feasible idea is suppression of one sideband.

Bottom of page 4 needs a statement to this effect: "All right, then, let's now have a look at methods that give this form of transmission. The first thing to consider is suppressing the carrier...." Hiatus now.

Having read it,

It is too goddamnable impartial. Too deep a subject for me to do my own deciding, I'm ready to accept the author's views, but I don't even know what he thinks. With almost no effort, he could make me think either way. It needs just a bit of bias here, since it really is headed somewhere -- to prove something or other,-- isn't it? "Further in proof of the futility of aspiring to so and so..... "Another example of the impracticability...."

(Imagine my urging bias here, condemning it in 2d paragraph)

fig. 5. A.L. Budlong, ARRL Communications Manager, added comments to this copy of Lamb's report.

ment of SSB in the 1930s, individual Amateurs did. James Lamb continued to think about it and proposed some interesting ideas — revolutionary in those days — including the transceiver concept of using the same oscillator for transmitting and receiving that is the backbone of all SSB transceivers today.

Fig. 6 shows an SSB generator using Lamb's crystal filter circuit. This sketch is dated June 18, 1933 — over 50 years ago. Notice the signatures of witnesses: F. Cheyney Beeklye, QST Advertising Manager, and Ross A. Hull, Associate Editor.

Another interesting and novel (in 1934) circuit for a modulator is shown in fig. 7. Here, two tubes are connected with the anodes in push-pull and their control grids in parallel. RF excitation is applied to the parallel connected control grids. This represents the carrier frequency, which is eliminated in the push-pull anode circuit. The audio information is connected, push-pull, into the suppressor grids. This circuit has the advantage that the RF and audio are kept

separated. (This disclosure was witnessed by Ross Hull.)

Probably Lamb's most dramatic development was the SSB transceiver sketched in fig. 8. This is basically the same block diagram as the SSB transceivers that began to appear on the market in the early 1970s. One slight difference may be interesting, however. Lamb perceived a receiver tuning problem with SSB. With AM, the practice was to tune to maximize the carrier. With SSB, this was no longer possible, because there is no carrier. To solve the receiver tuning problem, Lamb envisioned transmitting a 1 kHz tone; the receiver would be tuned until the 1 kHz tone was *actually* 1 kHz. When SSB systems came into actual use, the tuning problem was solved by Amateurs in a much simpler manner. Amateurs simply tuned the receiver until the voice sounded the most "natural."

Unfortunately, these developments in the use of SSB for Amateur communications were not publicized.

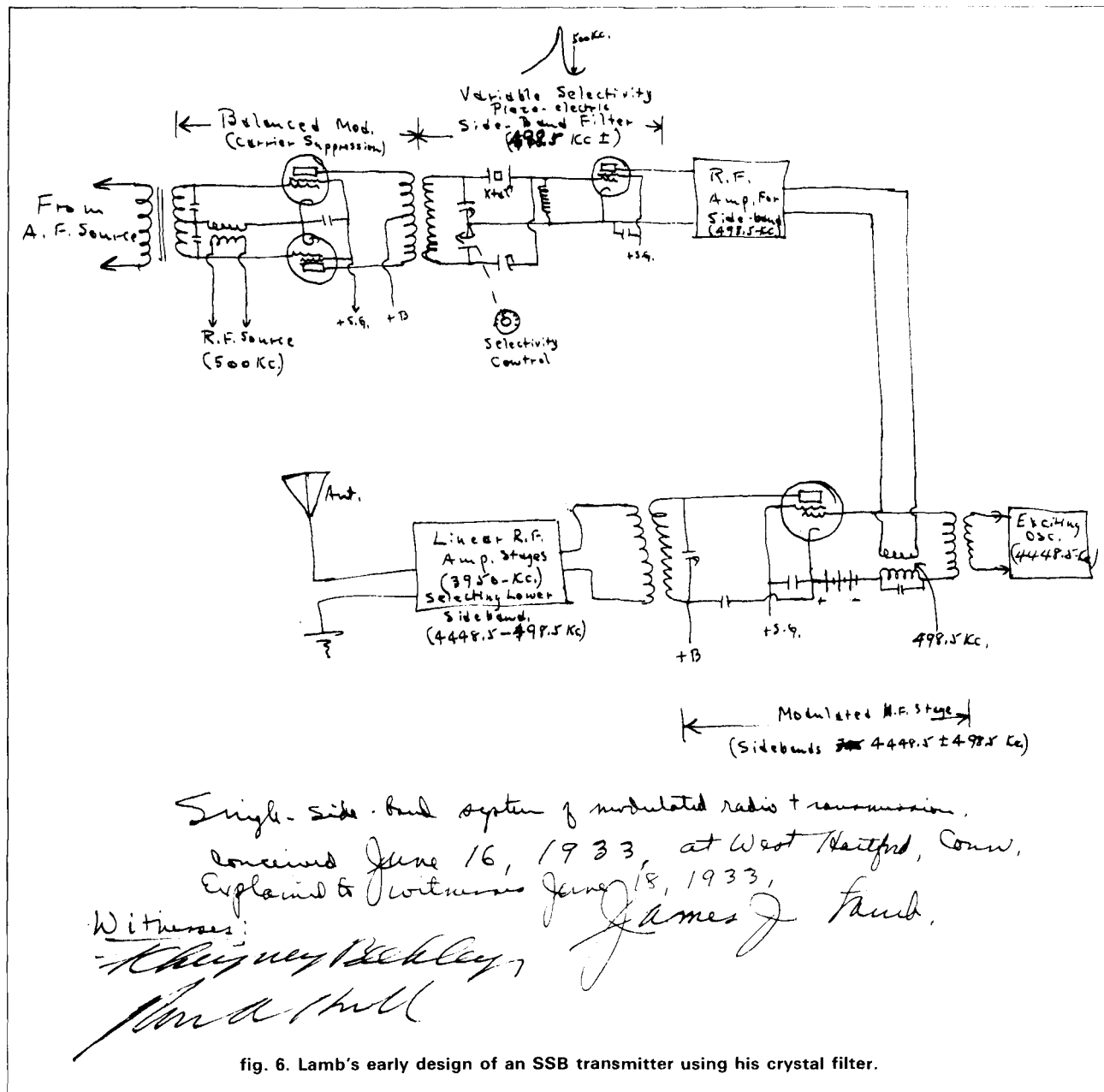


fig. 6. Lamb's early design of an SSB transmitter using his crystal filter.

Amateur SSB — phase two

The second phase in the development of Amateur SSB began during and immediately after World War II. O.G. Villard, then W6QYT, had become interested in SSB during the war. Although he was aware of Moore's work in 1934, he was intimidated by the filters required by Moore's rig. This apparent handicap led him to develop a phasing technique to generate SSB. As often happens to inventors, Villard discovered that the phasing technique had already been devised, and had been patented in the late 1920s.

The phasing technique offered the advantage of eliminating the need for elaborate filters and reducing

the number of frequency translations required. Filter technology was still in its infancy, and few Amateurs had access to the test equipment necessary for verifying a filter design. The biggest component problem lay in the design and construction of the required inductors, with adequate Q s in the required frequency range.

As most readers will recall, with the phasing method of SSB generation, two components of the carrier 90 degrees apart in phase are developed; this was not difficult to do in the early 1940s. Similarly, two components of the audio voltage — also 90 degrees apart in phase — are developed. This posed much more of a problem for Villard, who attempted to use one phase

unmodified and to develop a wide band, a 10:1 frequency range, and an audio channel shifted 90 degrees in phase. This proved to be a real problem because of the relative bandwidth required.

This problem was not solved until R.B. Dome⁶ showed that it was not necessary to actually shift the audio signal 90 degrees, but only to develop two audio voltages that were 90 degrees apart and then describe networks to do this. Fortunately, Dome's networks required only resistors and capacitors — no inductors. With this development, Villard was able to proceed with the actual construction of an SSB transmitter.

At the time, Villard was teaching electrical engineering at Stanford University. He and some of his students constructed an SSB transmitter using the phasing method and operated it on 20 meters from the Stanford Amateur Radio Club's station W6YX.⁷ Surprisingly, many Amateurs were able to copy SSB with their AM receivers; their reports were extremely

positive. Villard's transmitter used four 813 tubes in the output stage and was capable of much more power output than the filter-type transmitters of the time. The SSB signals were generated at the operating frequency (20-meter band) so that no frequency translations were required.

About ten days after Villard's group began transmitting, another SSB signal appeared on 20 meters. Arthur Nichols, then W0TQK, had built an SSB rig using the filter approach in only about five days, after hearing W6YX's SSB signal. This was a remarkable accomplishment, especially for that time; even today, most Amateurs would have difficulty building an SSB rig in five days.

filter approach to SSB

The January 1948 issue to *QST* featured an article by Nichols describing his SSB transmitter. Two related articles also appeared in this issue: one by Byron

In balanced amplifier using pentode-type screen-grid tubes, connected as diagrammed below, r.f. excitation is applied to control grids in parallel while (audio) modulating signal is applied to negatively-biased suppressor grids in series (phase opposition). R.F. output, consisting of side-band components, is taken from anodes in series (phase opposition). Side-band output with carrier component suppressed is the result.

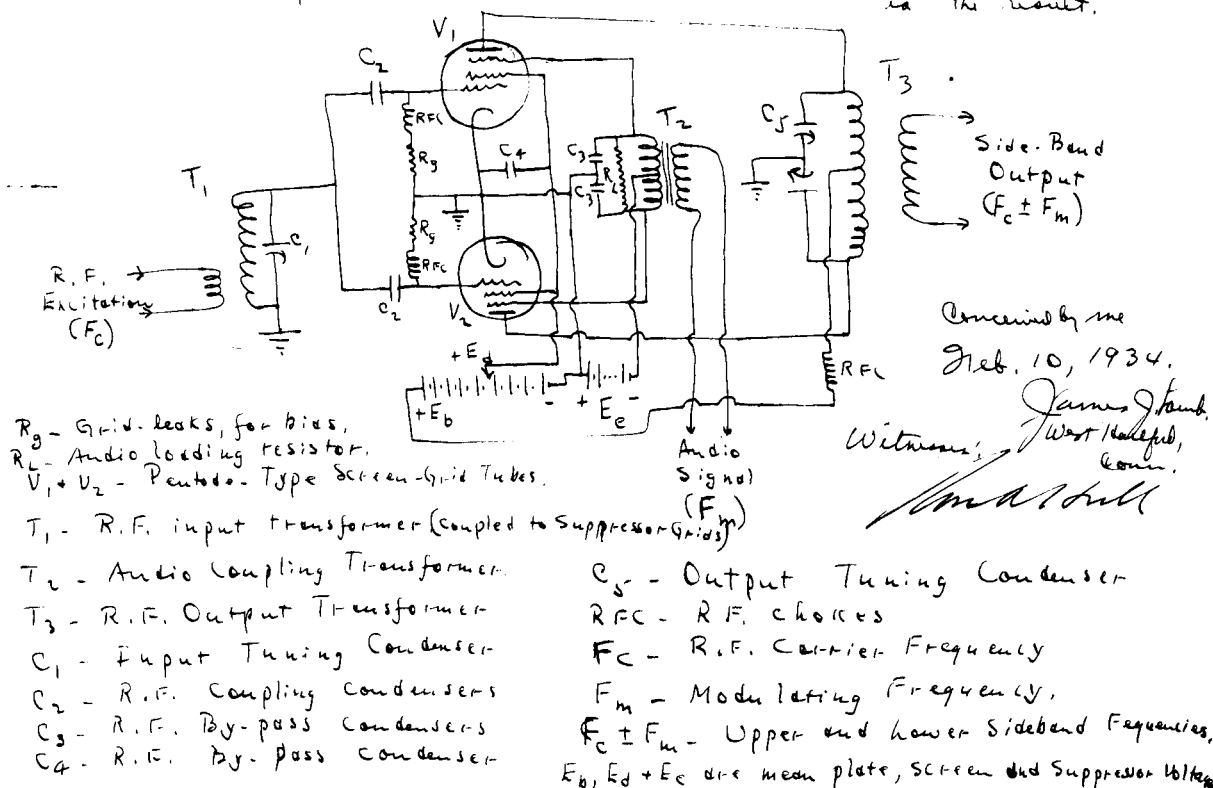
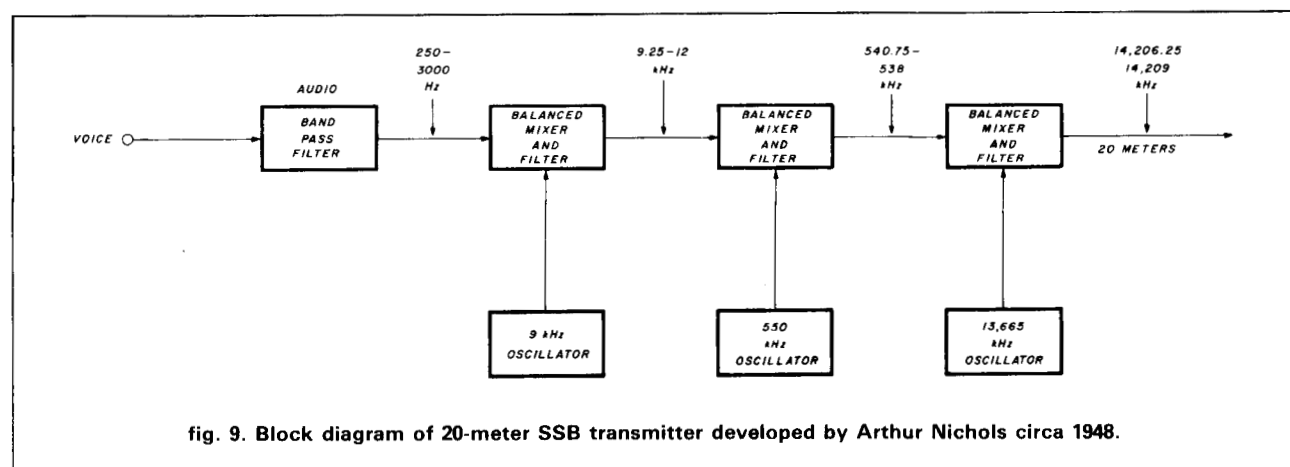
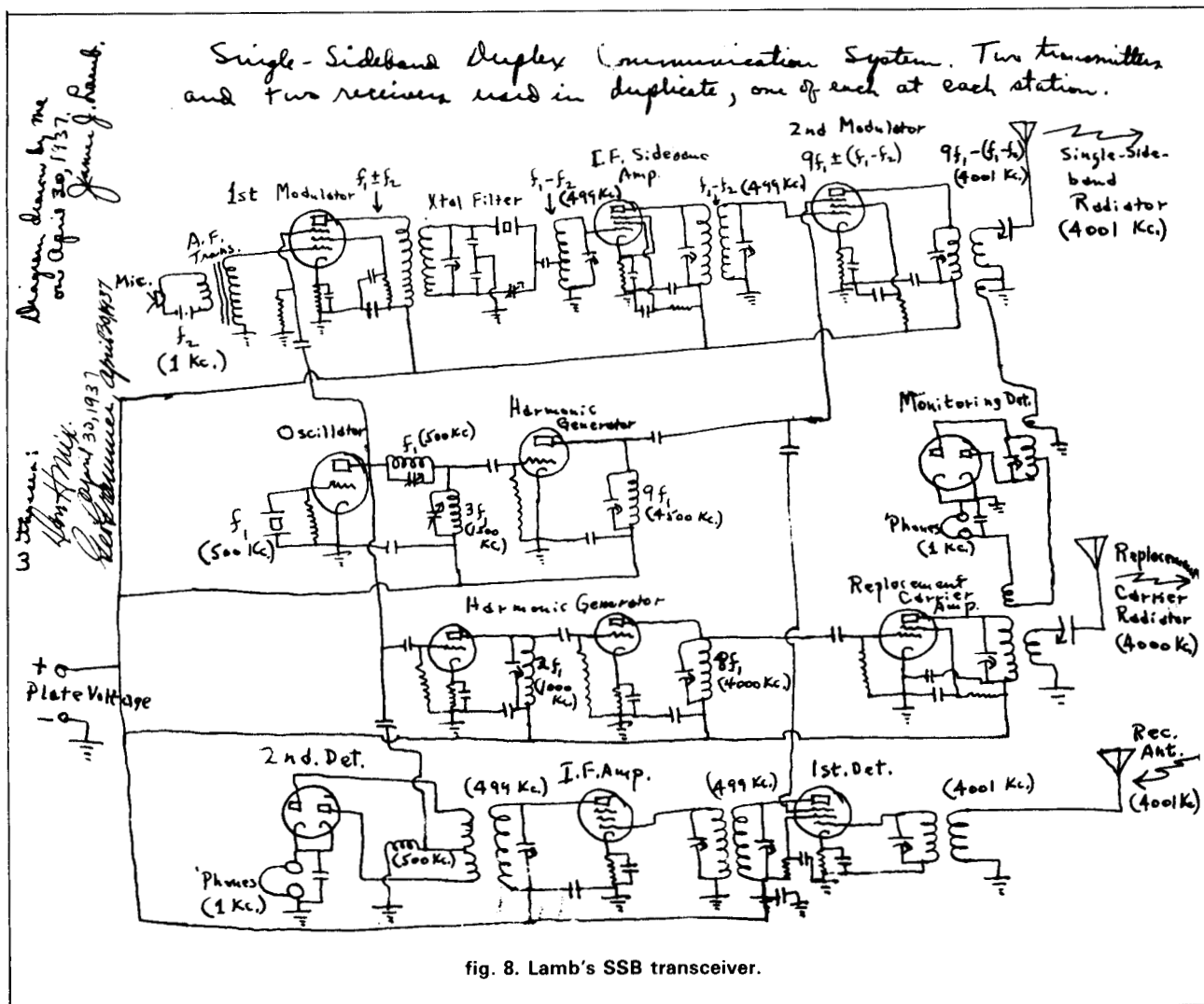


fig. 7. Modulator circuit separates RF and audio.



Goodman, W1DX,⁸ who explained the theoretical aspects of SSB, and a second by Villard,⁹ in which he described the early SSB on-the-air tests from W6YX.

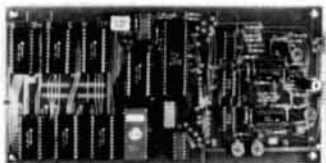
A block diagram of Nichol's 1948 transmitter —

similar to Moore's 1933 rig — is shown in **fig. 9**. Nichols used a 10-kHz filter to eliminate the carrier and undesired sideband with two frequency translations to 20 meters. Moore used two translations to 75

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meters. From a cursory examination, it appears that Nichol's and Moore's filters used Bell System technology; both appear to have been based on telephone carrier filters, with Moore using the next lower carrier channel slot than Nichols. Nichols obtained his filter from the late Fred Berry, formerly W0MNN.

By this time SSB enjoyed the active support of the League and others: additional theoretical material and improved techniques and equipment appeared in rapid order. In fairness, it must also be pointed out that the level of technical sophistication of the Amateur community had been greatly raised by the rapid development of electronics during World War II and by the large number of people introduced to the new technology both at home and in the field. This — coupled with the increase in the ranks of Amateur Radio operators and the fact that work done by Amateur Radio operators was more widely recognized — improved the political posture of Amateur Radio in its struggle against commercial and international broadcast interests in the battle for frequency allocation.

final comments

Arthur Nichols designed and built his SSB transmitter independently of other workers in the field. First licensed in 1931, he has always been a home-brew type, and is currently W6EVL in Fallsbrook, California.

In addition to the SSB transmitter Nichols used himself, he built two more transmitters which he sold to the National Company of Malden, Massachusetts. At the time, National was one of the leading manufacturers of Amateur equipment. I assume Nichols' transmitters were to be prototypes for a National SSB transmitter; if so, National could have had an early lead in supplying SSB equipment to the Amateur community. But National was unfortunately having financial problems and chose not to take advantage of the opportunity.

Nichols' interest in SSB came about naturally. His father was the late Dr. H.W. Nichols, an engineer with the Bell System who worked on the development of SSB radio equipment for transatlantic radio telephony service. Dr. Nichols was sent to England in 1923 to work with the British Post Office on arrangements to receive the Bell System transmissions mentioned earlier. While in England, he presented a paper before the British Institution of Electrical Engineers on the transatlantic radio telephone problem.¹⁰ The elder Nichols died in 1925 and did not live to see the long-term results of his work.

I have not been able to locate Robert M. Moore, formerly W6DEI, and I believe, with regret, that he may be a silent key. I would be happy to hear from anyone who knows (or knew) Moore, and particularly from anyone familiar with his interest in SSB.

acknowledgements

My thanks to Professor O.G. Villard, W6YX, Arthur H. Nichols, W6EVL, and James Millen, W1HRX, who reviewed an early draft of this manuscript and suggested changes, many of which have been incorporated.

My special thanks to James Lamb, who made his engineering notebook available to me, thus arousing my interest in the history of SSB.

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ham radio

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