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NBVM: Dawn of an Era or Promotional Hype?

—the performance and politics of Narrow Band Voice Modulation

In December, 1977, a well-known radio organization announced the development of "Narrow Band Voice Modulation," a breakthrough that would "revolutionize" voice communications. In the months that followed, two feature articles in *QST* and a chapter in the *Radio Amateur's Handbook* were devoted to NBVM. A prototype was developed and tested, and now a commercially-produced version of the system is in the hands of approximately 300 amateurs. If you are curious about the future in store for one of amateur radio's most publicized developments, read on.

At first glance, NBVM proponents have presented a number of highly beneficial reasons for adopting the system. Among those listed are:

1) Savings in spectrum. This is accomplished by reducing the bandwidth of your SSB signal to one-half its original size.
2) Significant improvement in the signal-to-noise ratio as a result of reducing bandwidth.
3) Better adjacent-channel rejection. This means cutting down on QRM.

In an age where our frequency allocations are threatened and the number of hams is growing, it is hard to criticize any proposal that would reduce congestion in the "overcrowded voice segments of the high-frequency amateur bands"—as one editor put it.

As a bonus, NBVM is supposed to increase your capability per Watt and reduce the bother of QRM! However, it is important to remember that performance, not promotional tactics, will be the deciding factor for the acceptance by the amateur radio community of any new communication system.

This article discusses the theory behind NBVM, evaluates the only commercial unit available, and offers some insight into the politics surrounding amateur radio's newest mode. Readers who are not technically inclined may want to skip the "How It Works" section and go directly to the later material on the performance and politics of NBVM.

How It Works

Narrow Band Voice Modulation is based on two methods of audio processing. The amplitude-compandor portion of the system compresses the amplitude of the signal. Expansion of the audio takes place at the receiving end. The concept of amplitude companding has been around for many years but did not become economically feasible until the development of large scale integrated circuits. The signal's bandwidth is compressed by using a frequency compandor. NBVM pioneer Dr. Richard W. Harris claims that this is a newly developed technique of audio processing.

The concept behind the amplitude compandor is a familiar one to many SSB operators. More efficient use of the transmitter power is obtained when the audio signal is compressed before it reaches the modulation stage. Compression and clipper circuitry have been the mainstay for most amateur speech processors. The problem of a noisy waveform arises when compression goes beyond the first few decibels of improvement. Characteristically, most hams using processors keep the level of compression low enough to avoid this problem. The NBVM system allows a greater level of compression since the receive station has an expander that reduces the noise level during the quiet part of the voice passage.

Many of the NBVM benefits rely on a reduction in bandwidth. Normal single sideband techniques use the voice information between 350 and 2400 Hz. The lower and upper responses are determined by the characteristics of the microphone and the filters built into your transmitter. The resulting carrier contains about 2100 Hz of usable audio.

I doubt if most audiophiles would praise the fidelity of a typical SSB signal, but the quality is more than adequate for everyday amateur use. Since SSB is the most effective method of rf modulation for voice communication presently in use, any conservation of bandwidth must take place in the audio frequency range. Accordingly, NBVM is known as a "baseband communications system." This allows any required processing scheme to be interfaced to the microphone and speaker lines of your rig, a much more pleasant concept than the alteration needed for rf processing.

Analysis of speech has shown that there are several parts of the audio spectrum that carry the information needed for acceptable intelligibility. Three such formants lie below 2500 Hz. It is important to remember that these formants are separated with noncritical spectrum between them. By removing these gaps, the frequency compandor portion of an NBVM unit is able to reduce the required audio bandwidth. The vocal chord sounds between the 400-Hz system rolloff and 600 Hz are passed through unaltered. The second and third formants are composed of voice sounds between 1000 and 2500 Hz. By mixing this audio with a 3100-Hz sine wave and filtering the output, the 1000- and 2500-Hz segments are folded into the 600-to-2100-Hz spectrum.

A further savings in bandwidth can be achieved by inverting and translating only the 1500-to-500-Hz segment. This means the output will fall between 600 and 1600 Hz. Fig. 1 shows a block diagram for a 1600 Hz frequency compandor.

The frequency compandor theory may look fine on paper, but the ability to translate it into a working model is what counts. The most important element of the design is the need for extremely sharp filters. Dr. Harris chose to use active-type filters for his prototype. Filter theory has been thoroughly discussed in previous amateur articles, so I will mention only the most important characteristics.

With the exception of a 700-Hz high-pass device, the filters in the commercial model are of the low-pass variety. The *QST* "construction" article states that they are based on 0.1-dB Chebyshev prototypes. They must exhibit a very small delay yet remain selective. The crucial 1600- and 2100-Hz filters have 16 poles each, while the remaining three use either 6 or 8 poles.

The resulting circuitry involves approximately 20 operational amplifiers. In order to ensure low noise and uniform gain, high quality TI074 bi-FET quad op amps are used. The resistors and capacitors used in the filters should have no more then one percent tolerance for best results. A great deal of attention must be paid to eliminating potential audio and rf feedback as well as troublesome ground loops.

Due to the complexity of the frequency compandor and the problems associated with discrete layouts, Dr. Harris and the VBC corporation developed six hybrid chips that contain most of the necessary circuitry. In addition to the filters, the VBC chips contain the 3100-Hz oscillator, balanced mixer, preamplifier, and buffers. Because the filters become saturated if the audio level gets too high, the voice signals

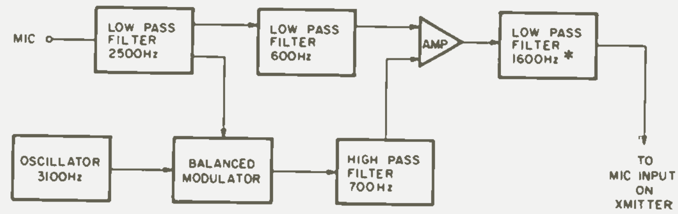

*Fig. 1(a). 1600-Hz frequency compandor used to transmit narrow band voice modulation. *2100-Hz low-pass filter is used in the wider frequency expander mode.*

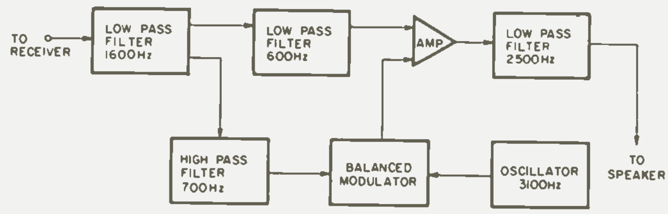

Fig. 1(b). 1600-Hz frequency compandor used to receive narrow band voice modulation.

are kept at around -10 dBm.

Several standard ICs are incorporated in the VBC design. These include an LM380 that gives one Watt of audio output during receive and an NE571 for the amplitude compandor. The power supply uses two garden-variety regulator chips. All of the system's active components reside on a 4.5" x 5.5" circuit board. A 44-pin edge connector provides connection to the inputs and outputs as well as to the switches and gain controls.

Theoretical and Test Performance

The *QST* articles on NBVM stressed the idea of ham experimentation to evaluate and improve the NBVM system. Prior to the availability of the VBC-3000 unit, very few high-frequency tests were conducted. Most of the performance data resulted from a study by the FCC's Land Communications Office. Their tests were oriented towards channelized SSB applications in the VHF commercial radio bands. The Commission's findings give some numerical indications of the effectiveness of NBVM.

When a 1600-Hz method (1300-Hz bandwidth) is used, the bandwidth of a normal SSB signal is cut in half. The broader 2100-Hz method (1800-Hz bandwidth) gives only a 33% savings. The smaller bandwidth can be interpreted as an improvement in the signal-to-noise ratio. The log (base ten) of the bandwidth in kilohertz is multiplied by 10 to obtain a comparative value. An unaltered SSB signal is computed to be 10 x log 3.2 = 5.05 dB.

Calculating the bandwidth factor for the 2100-Hz system gives 3.22 dB, and when the 1600-Hz setup is used, the value is reduced to 2.04 dB. The NBVM numbers are subtracted from the SSB value to give the improvement resulting from frequency companding. With the 1600-Hz filter, a theoretical improvement of 3 dB is achieved. Dr. Harris's description of the FCC results states only that a net improvement in the SNR was found. No numerical figure was given.

FCC tests also showed a 12- to 15-dB increase when only the amplitude compandor is used. Unlike the frequency compandor mode, improvement occurred when the received signal was measured straight through, without expansion. The *Radio Amateur's Handbook* states that amplitude companding becomes effective when the signal is several decibels above the noise level. Apparently, the expander requires a signal that is strong enough to act as a reference.

The VBC Model 3000

There were a number of comments in the early NBVM write-ups which suggested that many amateurs could get involved in NBVM tests by building their own baseband unit. Unfortunately, the detailed technical information dealt only with a system based on the VBC hybrid chips. Since most hams lack the ability or initiative to design and build a project of this magnitude, the only practical way to get involved was by purchasing a commercial NBVM transceiver. Only one model is available, the VBC Model 3000 Baseband Transceiver.

The 3000 is manufactured by Dr. Harris's company, VBC, and is marketed to amateurs by Henry Radio. One of the first units available (serial number 12) was acquired by *73* early last spring. Since then several cosmetic changes have been made in the 3000's design, but our unit functions identically to the newer ones.

The 6.5"W x 2"H x 9.5"D size is slightly smaller than a typical two-meter rig, and the Model 3000 weighs approximately two pounds. The two-piece grey cabinet contains the circuit board described previously plus the necessary controls and jacks that interface it to the real world. The user must supply 12.5-20 volts dc. VBC offers an optional wall-plug transformer that will meet this need. A 40-page operator's manual gives a thorough functional description and hookup information. The manual provides a number of tips for the NBVM, but it appears to be written hastily and includes a number of spelling mistakes.

There are two receive inputs, three receive audio outputs, two microphone inputs, and two transmit audio output lines. It is very important that the 3000 be properly matched to the microphone, speaker, and transmit/receive apparatus in your station. I found out the hard way! Attention must be paid to impedance matching if you want decent results. The amateur compatible microphone input can be varied to match a 500-50k-Ohm microphone by clipping two jumpers inside the cabinet. The stereo phone jack was factory wired to be used with a 600-Ohm rig. By swapping the 600-Ohm line with the high impedance output at the circuit board connector, I was able to hook the VBC system to a Kenwood TS-820 microphone input. An Astatic D104 microphone was used during the *73* tests.

Care must be taken to avoid applying dc to the Model 3000's audio connections. For example, the Icom IC-701 transceiver microphone line has a nine-volt potential used to power a preamp in the microphone. If you were not aware of this, serious damage might result to the baseband transceiver's protective capacitors when the 701 was turned on.

On the Air

The operator's manual suggests that a Model 3000 owner familiarize himself with the NBVM functions by using a tape recorder, before going on the air. Frequency-companded speech sounds far different than normal SSB when it has not been expanded at the receiving end. I found the tape recorder practice to be well worth the time. Once I was familiar with the unit and was ready to go on the air, I had to find another station with NBVM capabilities. Since there were no widely publicized NBVM nets or frequencies, I resorted to using the telephone to set up the first few contacts. Needless to say, NBVM is not in wide use.

The initial QSOs were very unsatisfying since the transmitter was not getting enough drive from the NBVM transceiver. This problem was solved by checking for and finding an impedance mismatch. When the gain controls on the 3000 and the transmitter are properly adjusted, there should be plenty of drive. This can be checked on most rigs by using the alc meter. I found that these adjustments were somewhat critical, and it was easy to overdrive the system, causing distortion.

When receiving NBVM signals, it is important to experiment with different rf and af gain settings on the receiver as well as the volume control on the Model 3000. The best copy was achieved when the rf gain was substantially reduced, although there was then degradation of the agc action. If good performance is desired, it is necessary to readjust the three receive and two transmit audio controls constantly. This is not a "set it and forget it" system.

Early narrow band publicity stressed that the frequency-companded signals could be copied by a station not equipped with NBVM. Since the second and third formants of the voice are inverted, they will be on the opposite sideband compared to the conventional signal. If the NBVM is transmitted on lower sideband, these formants can be understood by tuning in the signal on upper sideband. A more complete explanation is given in the "Listening to NBVM" box.

It is important to note that this is a very compromised situation. The level of intelligibility is low, and the advantages of NBVM aren't being used. It would be extremely awkward to conduct a QSO between an NBVM and non-NBVM station due to the need to change sidebands and turn the frequency compandor on and off. The ability to listen to NBVM without having a compandor is of little practical consequence.

The *73* tests were carried out under a variety of actual operating conditions. Although we did not perform a laboratory-style evaluation, several NBVM claims were confirmed. The amplitude compandor provides at least 12 dB of improvement, as long as the signal-to-noise ratio is positive. The amplitude compressor offers a number of advantages for everyday use. Simple tests on bandwidth savings showed that the 1600-Hz mode (1300-Hz bandwidth) provided no noticeable improvement. This result was confirmed by several other NBVM users, and the general consensus is that the 1600-Hz mode is the only beneficial one in terms of spectrum savings.

The most obvious benefit occurs during QSOs with stations which are weak and where adjacent channel interference (QRM) is causing problems. Provided the other station has NBVM, it may be possible to conduct a QSO when it would not be possible using conventional sideband. For day-to-day strong signal amateur activity, the VBC Model 3000 does not offer much in the way of improvement.

Bells and Whistles

One of the selling points of the 3000 is its multipurpose nature. A number of uses besides NBVM are suggested. These include having the unit serve as an audio amplifier or perhaps as the filter-power amplifier for a simple receiver. At one time, VBC was investigating the possibility of providing hybrid chips for such a receiver. If you experiment with digitally-based voice communications, the frequency compandor might offer some interesting possibilities. Commercial owners are using the 3000 to combine voice and data information on the same telephone line.

A more practical ham use of the 3000 could be as an auxiliary filter. Front-panel switches allow the user to select this option for receive only. The high quality of the filters make them useful for non-NBVM use. However, they are not specifically meant for this, and provide a compromise in this respect. The alternate functions do enhance the Model 3000's value, but they should not be considered when evaluating NBVM.

Pound for pound, the VBC Baseband Transceiver is probably not one of the better electronic buys available. The Model 3000 costs $349.00. A circuit board configuration is available for $279.00. The early model tested at *73* has poor quality switches which do not enhance the unit's value. The later version uses better parts, and as a result, it looks and handles better. The amplitude compandor is centered around an NE571 IC which has a single unit price of about $5.00. The major reason for the $349.00 price tag lies in the frequency-compandor circuitry. The overall dollar value of the 3000 is a subjective matter. I don't think the price is right to encourage widespread amateur use.

Another subjective area is the evaluation of the NBVM sound. I am certainly not a high-fidelity freak, but the frequency-companded speech does not have nearly as pleasing a quality as traditional sideband modes. As a result, I found it more difficult to fully comprehend the other stations. Any NBVM test should consider the factors of operator fatigue and enjoyment. Like any new system, it takes time to adjust to NBVM.

A Commercial Gold Mine?

Technological breakthroughs are not an everyday occurrence in amateur radio. No matter what the result is for the art of communications, politics is sure to be involved. NBVM is no exception. The circumstances surrounding its role in the amateur world has both current and historical implications.

Long before the first amateur test of NBVM, the system received careful scrutiny by the FCC. VBC, in cooperation with Stanford University and the FCC, tested NBVM as a possible means to reduce the size of channels needed for commercial VHF communication. In this scenario, the present FM land mobile systems would be replaced by SSB using narrow band voice modulation. This would allow between three and six times the current number of users.

Conflicting reports were presented to the Commissioners. The one referred to in the *QST* articles supported the NBVM claims and suggested further study. A second report raised a number of questions about the effectiveness of SSB/NBVM. It said there was a need for far greater frequency stability and that many intermod problems may occur if a narrow channel scheme is used. Although the report did not totally dismiss the idea of SSB/NBVM, it raised a number of objections. The industry reaction to NBVM has been cool, at best.

The current NBVM system is not the final version. VBC is developing a pilot carrier system that will automatically take care of frequency and gain control. It should be stressed that this is a substantial improvement over what is available now, but it is not readily applicable to HF

Listening to NBVM

If you do not own a frequency compandor, it still is possible to listen to the gang on NBVM. The results will depend on the receiver you use and your ability to comprehend less than ideal audio. The two formants of speech lying between 1000 and 2500 Hz are inverted into the spectrum lying between 600 and 2100 Hz. In the case of the narrow frequency compression, usable speech will be found between 600 and 1600 Hz. By tuning your receiver to the opposite sideband, it is possible to listen to these two translated formants. Tune slowly; a 20-Hz difference in frequency can be enough to make the signal unintelligible. If your receiver has a tunable passband filter, it may be possible to eliminate the first formant, below 600 Hz. It is in the other sideband and acts as QRM when you are trying to tune in the 600-to-2100-Hz segment. The 2100-Hz mode is not too difficult to eavesdrop on. The 1600-Hz mode requires you to have a good receiver and sharp ears. Remember, use the opposite sideband.

The best results for receiving NBVM obviously occur when you have a frequency compandor. If possible, establish contact on conventional sideband first. Carefully tune your receiver for the most natural sounding audio. If the transmitting station is using an amplitude compandor and you have an expander, adjust the receiver af gain (volume) so that no difference in the audio output level is heard when you switch the expander in and out. Then set the volume on your NBVM unit to a pleasant level. If the signal seems to blank out the expander, reduce the drive.

Now go to the frequency-companded mode. It will be possible to copy a compressed signal using either the 1600- or 2100-Hz filter in your expander, but the best results occur when your mode matches the transmitted signal. It may be necessary to make slight adjustments in frequency. This is best accomplished using RIT, a separate vfo, or a receiver/transmitter pair. It is essential to be able to tune within 20 or 30 Hz of the other station's frequency. Older receivers and some of the new synthesized rigs may present problems.

Readjust the rf and af gain controls on your receiver to obtain the best sounding audio. It may be necessary to turn off the agc if there is a strong signal on an adjacent channel. The i-f filtering in different rigs can influence the quality of the NBVM. Remember that a frequency-companded system will not offer the same intelligibility found on conventional SSB. Experimentation is the name of the game.

Following are some frequencies where NBVM activity is centered. The number of users is very small, so don't be surprised if there isn't much activity.

80 meters

3.850 MHz, Wednesdays at 0000 UTC (Tuesday night). This net meets prior to the East Coast AMSAT net on the same frequency.

40 meters

7.175 MHz, Saturdays at 0030 UTC (Friday night). This is an informal net of eastern stations.

20 meters

14.210 MHz—International calling frequency for NBVM.

14.235–14.242 MHz—Stateside NBVM QSOs can sometimes be found between these frequencies.

15 meters

21.302 MHz—Several DX NBVM stations have reported using this frequency.

amateur use.

Careful readers will remember that VBC has a system patent for parts of the NBVM system. At least one major corporation disputed the claim that Harris's frequency compandor design was original. It is easy to sympathize with VBC in its David vs. Goliath battle with the FCC and the big corporations, but the stakes are high. An FCC follow-up grant totalled $54,000, while production of 25 units a week for amateur use means a gross of $455,000 a year if all the units are sold. The private land mobile industry represents a potential market on the order of $12 billion if the FM gear currently in use is replaced. Obviously, VBC is very interested in being the sole supplier of NBVM hardware.

NBVM Is Dead and the ARRL Slew It?

It is easy to see how NBVM differs from earlier amateur radio developments like SSB and FM repeaters. The American Radio Relay League's involvement (or lack of it!) in these previous breakthroughs provides an interesting comparison to their NBVM affiliation. It was clear in the beginning that the ARRL would be the major backer of NBVM. Early publicity stressed that this was an experimental system that could be built and tested by amateurs. The much awaited *QST* "technical" information tarnished those claims. Since then, the Newington-based spokesmen for ham radio have quietly dropped NBVM.

Rumors abound concerning the League's involvement. It is clear that the initial support was based on a VBC demonstration tape which was not necessarily the most unbiased source. The *QST* articles and the *Handbook* chapter were published before the League staff had seen or tested a prototype. When tests were finally conducted, the inability to achieve the claimed benefits apparently left the ARRL in a corner. No W1AW tests have been conducted for the membership, and the League has turned its attention to other spectrum-saving techniques.

Despite the lack of independent supporting evidence, ads are appearing which claim that NBVM is the "most important innovation in amateur radio since SSB." Even though no concrete numbers showing the actual benefits to an HF amateur user are available, we are assured that the system is bound to succeed. Conflicting reports are given about the number of Model 3000s owned by hams. It is clear that many of the units are being tested by non-amateur users. The approach by those people commercially involved with NBVM is characterized by a lack of organization, poor technical documentation, and, in some cases, evasion.

Although early NBVM publicity urged us to exercise the ham tradition of experimentation, Model 3000 owners are cautioned by VBC not to "attach improvised circuitry anywhere on the printed wiring board." Despite the appliance operator's approach taken by VBC, there is amateur involvement in baseband communications experimentation. At least one ham has built an NBVM unit based on digital filters, and there are several designs being tested that don't rely on single-source chips.

Conclusions

During our on-the-air testing with other amateur stations equipped with the VBC Model 3000, we did not encounter a single situation in which NBVM was superior to ordinary SSB, although a few of the operators we contacted said they had found an advantage to using NBVM under certain conditions. Another point to remember is that the spectrum-saving frequency-companded mode is useful only when the stations at both ends of the QSO are equipped for NBVM.

Reception of frequency-companded signals on an ordinary receiver is possible, as outlined in the accompanying "Listening to NBVM" box, but the process is cumbersome and the fidelity is quite poor. A successful contact between an NBVM station and a non-NBVM station is an extremely unwieldy method of communication. It's doubtful that amateurs without NBVM will have much interest in participating in NBVM testing. Although such participation was suggested in the September, 1978, issue of *QST*, there is little useful information which non-NBVM stations can gather by listening to frequency-companded signals.

It would be shortsighted simply to dismiss a technology that promises more efficient use of the amateur bands. However, it is equally shortsighted to jump at the first new technique to come along and begin promoting it as the most important innovation since single sideband. This tends to discourage exploration of other promising methods such as digitalized speech, time multiplexing, and synchronous detection.

Regardless of the methods used to achieve a savings in spectrum, the advantages of reduced bandwidth, power savings, and signal-to-noise ratio improvement must be weighed against the increased complexity, loss in fidelity, and higher cost. When SSB was introduced, most amateurs were skeptical of the new mode, much as they are now skeptical of NBVM. In the case of SSB, though, its clear superiority over AM convinced the skeptics; the benefits obviously outweighed the costs. After our tests, we at *73* do not believe that NBVM, as applied in the VBC Model 3000, offers that same clear superiority over our present modes of communication.

More experimentation with reduced-bandwidth techniques is needed. Also, it's important that ideas be shared among experimenters. If you are having success with any reduced-bandwidth system, including VBC's Model 3000, be sure to document your work, write it up, and send it to us for publication in *73*. Let's all work together to develop a viable system.■

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