Proceedings of

The Radio Club of America, Inc.

Volume 62, Number 2 | November 1988

Founded 1909

We are Grateful for this Holiday Season that makes it fitting to pause.... in consideration and appreciation of the friendships made.... and to wish you

Merry Christmas and

Happy New Year

THE RADIO CLUB OF AMERICA, INC.

Founded 1909, New York, U.S.A.

The Radio Club of America, Inc.

324 SOUTH 3rd AVENUE, HIGHLAND PARK, N.J. 08904

Price $2.50

Organized for the interchange of knowledge of the radio art, the promotion of good fellowship among the members thereof, and the advancement of public interest in radio.

CONTENTS

Guest Editorial

THE RADIO CLUB OF AMERICA LEGACY FUND

In March, 1988, the Club began formally recording contributions to **The Legacy Fund.** The fund was established as a vehicle for contributions to the Club from the estates of members and friends. It is intended for the general welfare of the Club and for support of various programs as needed.

The principle of The Legacy Fund had been introduced with a bequest of $2,700 from the estate of Monte Cohen in 1982. Those moneys were combined with other contributions and used to obtain two Tandy computer systems. These were used by the Treasurer and Executive Secretary and were the forerunners of our current computerized records operation.

Following the death of Jack Poppele (H) in 1986, his family contributed a sum in excess of $10,000 to the Club. A year later, Alfred H. Grebe, Jr. (F) donated $10,000 in memory of his father, Alfred H. Grebe (F). Those sums were used to establish scholarship funds in the names of Jack Poppele and Alfred H. Grebe, Sr. From the interest earned on those funds and other Grants-in-Aid contributions, scholarships in the amount of $6,500 were awarded this year.

So there are two examples of the current use of bequests. Future bequests might make possible a number of publications commemorating important historical events in the chronology of communications that have been proposed. In having a convenient source of temporary funds, we would have many more options for the completion of some of these works. It is not always possible to raise money in advance of the publication date, yet it is always needed for the preparation, supplies, printing, and distribution.

The Club's membership records have been computerized for several years now, and we are continuing to expand the use of computers in our operations. Recently, we have been using the computer to help us with publication tasks such as word processing, layouts, and actual typesetting. The donation of a Tandy 1000 computer system by Jay R. Huckabee, W5EPJ (F) has given us a solid entry in the world of IBM-compatible personal computing systems with the advantages of a wide variety of highly-refined software.

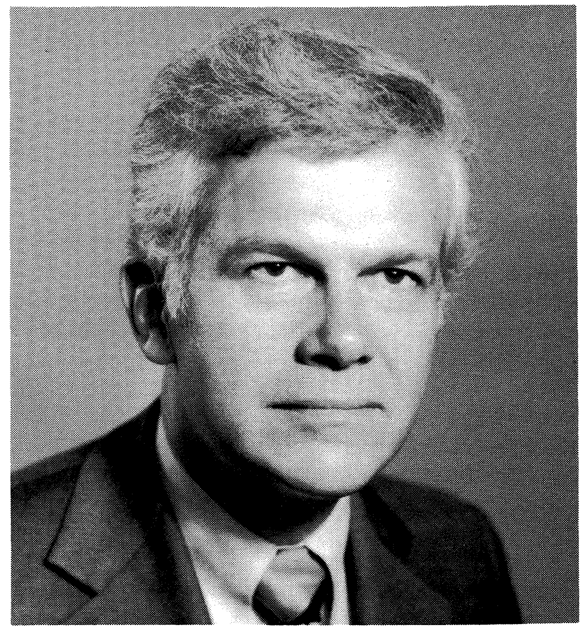
Finally, we must recognize the inexorable pressures of inflation. We are working hard to maintain the high standards we have set for our publications and member services, without raising dues. This past year, for example, we experimented with combined mailings and reduced the number of publications. In addition, we developed a high cost-consciousness and improved our budgeting, but costs always seem to rise at the wrong times . . . and too precipitously.

The Legacy Fund might prove to be "just what the doctor ordered" if we remember to include the Club in our bequests. If you would like more information, drop a line to Director Arch Doty Jr., K8CFU, 347 Jackson Road, Fletcher, NC 28732-9518. He'll be happy to coordinate receipt of bequests and to supply you with appropriate language for codicils, subject to review by your attorney.

E.D. Stoll, Ph.D.
Treasurer

POWER-side® COMPATIBLE AM/SSB BROADCASTING SYSTEM

by Leonard R. Kahn (M 1953, F 1961)



Leonard R. Kahn was awarded the Armstrong Medal at the 1980 Annual Awards Banquet in recognition of his work in AM stereo, independent sideband, time diversity, voice processing, and other advanced electronic techniques. He presented an outstanding address in response to the award in which he urged a reform in the U.S. patent system. He is president of Kahn Communications, Inc.

This paper originally was published in the IEEE Transactions on Broadcasting, Vol. 34, No. 3, September 1988, and simultaneously published in Japan by "Broadcasting Engineering", Vol. 41, N. 8.

A slightly modified version of the paper was presented by Mr. Kahn at the Technical Seminar of the Radio Club of America on November 18, 1988, at the New York Athletic Club.

ABSTRACT – The Independent Sideband system of AM Stereo can, by use of special audio processing, significantly improve monaural reception. The resulting transmitted signal, called a *"POWER-side"* signal, allows listeners to "sideband tune" with new types of mono receivers so as to reduce co- and adjacent-channel interference, improve the effective fidelity of the AM receiver, and make the receiver's tuning significantly less critical.

Furthermore, due to the inequality of low frequency sideband components, the system reduces selective fading, antenna null distortion and re-radiation problems when the *POWER-side* signal is received by both "side-band tuned" mono receivers as well as digitally-tuned stereo and mono receivers which center tune to the carrier frequency.

Most importantly, this type of wave substantially reduces co-channel "beating" effects that have, since the earliest days of broadcasting, plagued AM signal reception.

INTRODUCTION

AM broadcasting's main advantage vis-a-vis FM broadcasting is superior coverage. FM provides a superior signal when the signal-to-noise ratio is high but AM can, if properly implemented, provide usable signals at far lower pre-demodulation signal-to-noise ratios. Thus, AM is a more rugged form of modulation. Added to AM's superior ruggedness is the coverage advantage of operating at a frequency range of 540 to 1600 KHz rather than in the FM band of 88 to 108 mHz.

The optimum form of amplitude modulation is single-sideband (SSB) with reduced or suppressed carrier. SSB is the most rugged form of analog modulation and also occupies the least bandwidth. While the advantages of SSB were known by many of the pioneers of AM broadcasting, the complexity of SSB receivers restricted SSB's use to commercial, military and amateur applications. However, circuit complexity is no longer a deterrent with the advent of integrated circuits.

There is, unfortunately, a much more serous problem impeding the introduction of SSB operation, and that is the public's huge inventory of envelope-detector type receivers.

Accordingly, the transition from standard double-sideband AM transmission to the optimum SSB forms of AM transmission, (suppressed carrier SSB for monophonic stations and reduced-carrier independent sideband for stereophonic transmissions), must be gradual.

The purpose of this paper is to describe *POWER-side*™ a system that, the author believes, in addition to alleviating some of AM radio's most serious technical problems, can be used to make the transition from conventional double-sideband (DSB) AM to SSB swifter and more graceful.

WHAT IS *POWER-side?*

POWER-side is a form of amplitude modulation which offers some of the transmission advantage of single-sideband (SSB) and which is compatible with both envelope-detector type receivers and SSB receivers incorporating synchronous demodulators. Furthermore, since a *POWER-side* signal better matches SSB receivers than does a conventional AM signal, this new form of transmission should help to expedite to widespread use of these superior SSB receivers.

A *POWER-side* wave is an AM wave having at least a substantial part of one sideband raised in level and the other sideband reduced in level, so that the total envelope modulation is unaltered. The stronger sideband is transmitted free of pre-emphasis, but the weaker sideband incorporates substantial pre-emphasis in order to insure full compatibility with center (carrier) tuned receivers.

Thus, *POWER-side,* while similar to Compatible Single Sideband[1] (CSSB) in use in the air-to-ground communications, is really an independent sideband, Kahn/Hazeltine type, AM stereo wave. (Indeed, *POWER-side* transmission can be implemented using either of the two FCC type-accepted Kahn Communications' stereo exciters (models STR-77 or STR-84) and a special audio processor.)

The reason for the change in emphasis from a CSSB transmission to one based on the independent sideband AM stereo system is the recent widespread use of pre-emphasis in AM broadcasting. A second sideband is needed to support pre-emphasis while still allowing listeners to "sideband tune" to a stronger sideband. (See Below). It is clear that AM broadcasters, faced with serious decline in the fidelity of receivers during the past two decades, are now forced to use large amount of pre-emphasis in order to achieve some semblance of overall fidelity. Thus, given the deplorable state of AM receivers, any new AM transmission system must be able to accommodate pre-emphasis.

As mentioned above, *POWER-side* waves are generated by standard AM transmitters excited by type-accepted Kahn/Hazeltine system AM Stereo units. Taking a very firm conservative stance in terms of occupied bandwidth and minimizing adjacent channel interference, all of these AM Stereo exciters incorporate low-pass filters in the L-R branch.

For example, in the early STR-77 model the lowpass filter was set for 5 kHz, restricting separation to approximately 6 kHz. The new STR-84 model restricts separation to 7.5 kHz. Therefore, *POWER-side* is not effective for frequencies above 7.5 kHz.

Furthermore, since substantial pre-emphasis is used on the weak sideband and no pre-emphasis is used for the stronger sideband, at approximately 5 kHz the two sidebands reach the same level. Thus, the *POWER-side* effect is restricted to the low and medium frequency range of voice and the low frequency range of music. Nevertheless, since a very large percentage of the intelligibility of voice and the fundamental components of musical instruments are at relatively low frequencies, the effects of the frequency limitations imposed on the *POWER-side* system are not substantial as one might expect. (It should be noted that these limitations pertain only to the difference in the treatment of the two sidebands. The overall envelope modulation of the *POWER-side* wave is not restricted and can be used to transmit components up to 15 kHz.)

Block Diagram of a Practical *POWER-side* Transmission System

FIG. 1 shows, in block form, the basic structure of a *POWER-side* system. The audio signal, that comprises all of the necessary components for monophonic listeners, feeds a de-emphasis circuit. This de-emphasis circuit should be adjusted to match the inverse of the pre-emphasis curve used by the station.

Thus, a signal with relatively flat frequency response should appear at the output of the de-emphasis circuit. The output of this circuit feeds an attenuator which reduces the audio level so that the signal has a level that will produce a weaker sideband approximately 15 db below the stronger sideband.

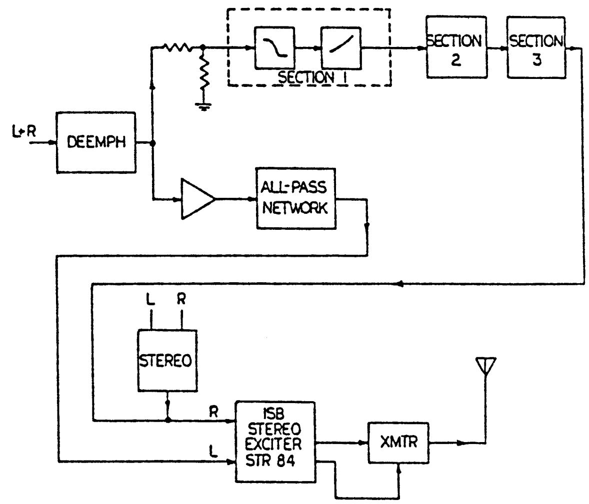


Figure 1.

In other words, assuming the total envelope modulation produced by both sidebands is 100%, the sideband level for the weaker sideband should cause approximately 15% envelope modulation and, therefore, the stronger sideband is increased from a level that would normally cause 50% of the envelope modulation to one that causes 85% of the modulation.

The output of the attenuator feeds one of three equal sections that produces the desired increased pre-emphasis for the weak sideband. The first segment of Section 1 is actually a lowpass filter with a "stop" region limited by a bypass stage.

The second segment of Section 1 introduces a rising response characteristic which is greater than the effect of the prior block. Accordingly, the overall effect of the two segments is to produce a characteristic peaking at 5 db, for 5 kHz (relative to 500 Hz).

Sections 2 and 3, since they are identical to Section 1, make for a total response of three times that of Section 1, i.e. producing a 15 db peak on the weaker sideband.

As shown in FIG. 1, the output of the de-emphasis circuit, in addition to feeding the increased pre-emphasis circuitry for processing the weaker sideband, feeds an amplifier. This amplifier causes the audio level driving the stronger sideband to be proper to elevate the level of the sideband to 85% of the total envelope modulation at 1 kHz.

The output of the amplifier feeds an "all-pass" network which has a phase characteristic that closely approximates that of the overall additional pre-emphasis network in the weaker sideband path. Accordingly, the two sidebands should be approximately in phase, maximizing envelope modulation.

The two-path audio processing system feeds the appropriate L and R inputs of an independent sideband type AM stereo exciter, such as Kahn Communications' Model STR-84.

For example, if it is desired to enhance the lower-sideband, the output of the "all-pass" network is connected to the L input of the exciter and Section 3 output is connected to the R input. The stereo exciter causes the transmitter to produce the desired *POWER-side* RF wave.

It should be noted that a "stereo effects" wave may be added to the audio signal feeding the weak sideband so as to enhance the wave received by stereo listeners. The "stereo effects" signal can take many forms[2], including a special stereo component or certain stereo sounds such as "crowd noise" for a sporting event. (A future paper is planned to discuss further *POWER-side* developments as well as those pertaining to stereo transmissions effects.)

Sideband Tuning

The term "Sideband Tuning", as used in the following, is defined as the tuning of a receiver so as to favor the desired sideband of a *POWER-side* wave. When radios with reasonably flat IF selectivity characteristics are used, one edge of the receiver's passband will fall at approximately the station's carrier frequency in the same fashion as when a conventional SSB receiver is tuned to an SSB wave.

Listeners tuning to a *POWER-side* signal will naturally tune to the stronger sideband because it is louder. Early tests on Compatible Single-Sideband (CSSB) showed that the amount of sideband tuning is a function of the signal-to-noise ratio. The poorer the signal-to-noise ratio the further the listener will tune over towards the sideband and away from the carrier in order to improve intelligibility.

It has been experimentally demonstrated that the optimum amount of "sideband tuning", for typical narrowband AM radios, is of the order of 2.2 to 3 kHz. The actual amount of "sideband tuning" used is a fuction of the receiver's selectivity characteristic and the cleanliness of the *POWER-side* signal.

Thus, stations that wish to obtain the full benefits of "sideband tuning" will find it necessary to transmit clean signals, thus avoiding negative-going overmodulation, harsh audio-processing procedures and significant amounts of incidental phase modulation in their transmitters[3]. An important by-product of *POWER-side* operation is that all stations using the system will find it advantageous to improve their signal purity, reducing splatter and other sources of adjacent channel interference. (It is pointed out below that *POWER-side* also effectively reduces the so-called "carrier beat" co-channel interference effect.)

The optimum "sideband tuning" point (for a perfect *POWER-side* signal) is the same as it would be for conventional single-sideband (SSB) operation; i.e., tuned to the desired sideband with one of the receiver's passband edges at the carrier frequency.

As an example, assume that the receiver's IF passband is 6 kHz. It should theoretically support 3 kHz audio response when center or carrier tuned to a dsb AM wave, and 6 kHz when tuned to an SSB signal. (Unfortunately, for the AM broadcast industry, current (1988) receivers with 6 kHz passbands may be considered to have reasonable bandwidth and receivers with 4.4 kHz bandwidths are not unusual!) Experiments with a number of *POWER-side* stations show that tuning 2.2 kHz to 3 kHz from the carrier towards the stronger sideband turns out to be an optimum "sideband tuning" point, providing 4.4 to 6 kHz (-6 db) audio fidelity.

It is interesting to note that the matched filter concept of Information Theory would lead to a similar conclusion. In other words, since modern broadcast receivers have such a narrow band characteristic, the *POWER-side* signal better matches typical AM receivers. Thus, the implementation of *POWER-side* signals is consistent with the Matched Filter theory.

Accordingly, typical narrowband AM radios better match one sideband of a *POWER-side* wave than they match the two sidebands of the conventional dsb AM waves which they were designed to receive. In any case, "Sideband Tuning" to *POWER-side* signals, offers almost an effective 2-to-1 gain in frequency response for typical narrowband home and portable radios.

Reduction of Sideband Cancellation Effects

The classical amplitude modified wave has a serious weakness. The two sidebands of an AM wave are of equal amplitude, thus making the wave particularly sensitive to the relative phase of its three components. For example, if the carrier is rotated relative to the sidebands by 90 degrees, the wave is converted from a pure amplitude-modulated wave to a form of phase modulation (quadrature modulation) where there are no desired signal components present in the envelope of the wave.

In other words, the fact that the sidebands are equal in amplitude makes it possible for the desired demodulated audio waves derived from the two sidebands to completely cancel under certain conditions, such as selective-fading multipath conditions, etc.

Since the sidebands of a *POWER-side* wave are unequal, it is a much more rugged wave.

For example, conventional equal amplitude sideband AM waves suffer from a complete loss of fundamental modulation whenever the carrier is shifted odd multiples of 90 degrees; i.e., ±90 degrees, ±270 degrees, etc. In comparison, the *POWER-side* wave loses only 2.7 db under these same conditions. (See FIG. 2)

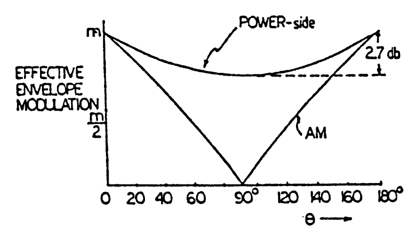
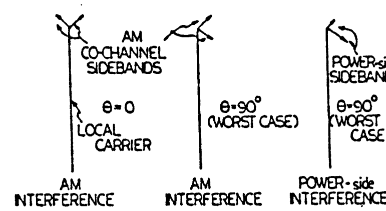


Figure 2



It is noteworthy that the use of a synchronous demodulator[4] does not, in any way, alleviate such losses of fundamental modulation.

It should also be noted that, unlike these advantages of *POWER-side* that are based upon "sideband tuning", the advantages based upon the reduced phase sensitivity of the *POWER-side* wave are available for all types of radios, including digitally tuned radios which center tune to the carrier frequency.

SUMMARY OF ADVANTAGES:

The advantage of the *POWER-side* system are of two basic types:

1) Those due to "Sideband Tuning"; and

2) Those due to reduction of sideband cancellation effects.

Obviously, in order to gain the "Sideband Tuning" advantages, listeners must use a receiver that can be tuned to a sideband such as: a) continuously tunable radios, or b) special digitally-tuned radios that can be stepped in no more than 2 kHz steps, or c) a new type of digitally-tuned radio specifically designed for "Sideband Tuning".

The advantages based upon the reduction of sideband cancellation effects are available with all types of receivers, including digitally-tuned radios which center tune to the carrier frequency. Generally, sideband cancellation effects are further enhanced by "Sideband Tuning", as the pre-detection spectrum of the wave is caused to have additional asymmetry.

Brief Description of the Advantages of "Sideband Tuning"

1) **Increased frequency response.** The frequency response of most receivers is limitd by the IF or RF selectivity characteristic. As discussed above, "Sideband Tuning" almost doubles the overall frequency response of narrow-band receivers.

2) **Reduced adjacent channel interference.** "Sideband Tuning" causes splatter and adjacent channel carrier whistles to fall at a substantiallly lower point on the RF and IF selectivity curve. Furthermore, sideband tuning, by increasing the effective fidelity of the desired received signal, enhances critical sibilant sounds and other mid- and high-frequency sounds, raising their effective signal-to-interference ratios. Since sibilants are weak and generally are the first common sounds to be lost in interference, improving their level significantly improves intelligibility in fringe areas.

3) **Reduced co-channel interferences** due to "Sideband Tuning". (See section below treating "carrier beats", where a much more important advantage is described.) Assuming that the interfering AM station continues to transmit normal, equal amplitude sidebands, the desired station gains up to 4.7 db in addition to the other advantages of "Sideband Tuning".

The station that continues to utilize conventional AM transmission might be expected to gain even a greater advantage than its co-channel neighbor using *POWER-side.* The reason is that the *POWER-side* signal's weaker sideband is reduced approximately 10 db while its stronger sideband is raised only 3.5 to 4.7 db. The flaw in such reasoning is that, absent special *POWER-side* receivers, listeners should not be expected to "sideband tune" their receivers as would listeners to *POWER-side* equipped stations. However, if the two interfering stations, cooperate and both transmit *POWER-side* signals enhancing opposite sidebands, a very significant advantage can be achieved. In this case, as much as 15 db improvement in signal-to-interference ratio can be achieved with high selectivity receivers. (Also, as discussed below, they will both enjoy freedom from serious "beating" problems.)

On-the-air *POWER-side* operation by WMCA, New York, 570 kHz, favoring the upper sideband, and WSYR Syracuse, 570 kHz, favoring the lower sideband, has achieved very substantial interference reduction for both stations. Actually, WSYR has reported that at night, some seven miles from the WSYR transmitter and approximately 250 miles from WMCA, one is able to hear an intelligible signal from WMCA when using an independent sideband type AM stereo receiver.

4) **Less Critical Tuning.** Typically, receivers tuned to a *POWER-side* signal can be sideband tuned from as much as 3 kHz. Thus listeners can tune their radios from as much as 300 Hz on the "wrong side" of the carrier, to 3,000 Hz on the "correct" side, for a total of 3300 Hz spread. In comparison, typical AM signals, utilizing a similar pre-emphasis characteristic, would cause tuning to be limited to approximately ±300 Hz. Thus, the improvement is over five times the normal tuning range.

Brief Description of Reduction of Sideband Cancellation Effects

The relative insensitivity of a *POWER-side* wave, in comparison to the conventional AM wave, results in the following advantages which conform the ruggedness of a *POWER-side* wave:

a) Significant reduction in the selective fading distortion and the depth of the fades;[5]

b) Reduction in distortion in antenna nulls, as well as less loss of modulation in these critical locations[6]

c) Reduction of distortion and less loss of modulation due to reradiation from buildings and power lines:

d) And, most importantly, a dramatic reduction in the beat interference caused to other co-channel stations.

As pointed out above, *POWER-side* advantages a) through d) exist for all types of receivers, whether continuously tunable or digitally tuned.

Co-channel Interference Reduction

There are two distinct aspects to an analysis of the interference characteristics of modulation systems:

1) How does the modulation system influence interferences to other stations; and

2) How does the use of the system influence the interference heard by the station's own listeners?

The latter aspect has been treated above. It is now useful to consider how *POWER-side* operation will affect a station's co-channel neighbors.

Actually, in the long run the most important advantage of *POWER-side* operation may be that the system reduces co-channel interference effects. The reason for this important *POWER-side* characteristics can be best seen by examining the phenomenon commonly (and the author believes improperly) called "carrier beat".

A beating sound is most annoying and creates far more listener annoyance than does normal interfering speech or music. Thus, a clean voice signal (absent beating effects), say 30 db below a desired signal, produces far less disturbance than does a voice signal having the same level but suffering from beating effects.

The term "carrier beating" is generally used to describe this phenomenon. However, it is believed that this term is not truly descriptive of the problem. Typically, co-channel interference beat rates are less than a few Hertz. Such low frequency waves are greatly attenuated by the frequency response of a receiver's amplifier and loud speaker system. Indeed, listeners cannot hear such low-frequency sound waves even though they can feel very-low-frequency vibrations.

One can hear the slow variation in noise level caused by the variation of gain of AVC controlled amplifiers. However, even moderately severe co-channel interference of 20 db, causes the gain of the AVC controlled amplifiers to vary by only 1.74 db, and for interference 30 db below the desired signal the total variation is 0.5 db.

Actually the phenomenon that listeners do hear might best be called "sideband beat". The fact that sidebands beat under normal interference conditions can be understood by considering the following situation where:

1) the frequency of the desired (strong) signal is 900 kHz and the weaker co-channel carrier is 1 Hz higher, i.e. 900.001 kHz;

2) the desired signal is temporarily free of modulation, ("dead air"); and

3) the interfering signal is modulated by a 1 kHz tone.

Since the stronger (900 kHz) carrier dominates the demodulation process, (the envelope detector controls the switching function) the lower sideband will produce a significant demoduation product at a frequency of 999 Hz. The upper sideband produces a demoduation product having a frequency of 1001 Hz. Both of these equal amplitude waves easily pass through the receiver's audio system and are audible to listeners. The beat rate caused by the difference in the frequencies of the upper and lower sideband demodulated audio signals will be 2 Hz or *two times the carrier frequency difference.* (See Appendix A.)

Thus, under normal two-station co-channel interference conditions, the receiver output will be contaminated with two distinct audio signals having a difference in frequency of two times the carrier error.

Referring to FIG. 2, it is seen that conventional AM waves suffer a wide range of effective modulation, from full to complete nulls. On the other hand, a simplified analysis shows that a *POWER-side* wave only suffers a total variation of 2.7 db under the same condition.

In order to experimentally verify the reduction of co-channel beat type interference, a simple, but convincing, experiment was performed. A multi-system AM stereo "boom box" type portable radio, Sanyo model MW-250, operating in the monophonic mode, was tuned to two *POWER-side* stations (WMCA 570 kHz New York, and WTHE 1520 kHz Mineola, Long Island) at Kahn Communications' laboratories in Westbury, New York.

The output of a Hewlett Packard model 606B signal generator was loosely coupled to the input of the Sanyo MW-250 receiver. One of the two *POWER-side* stations was tuned in and the signal generator was adjusted to match the received carrier frequency within 2 Hz.

The output level of the signal generator was adjusted for maximum beat effects, indicating that the signal generator was producing the same signal strength as the received broadcast signal. The output attenuator of the signal generator was then switched, so as to raise the level of the signal generator by 20 db. This properly simulated a strong unmodulated local signal being interfered with by a *POWER-side* signal.

The resulting audible interference from voice and music signals was almost completely free of any beat-type phenomenon.

For comparison, the receiver was tuned to WOR, a New York station transmitting a conventional AM signal and the same procedure produced the very annoying conventional beat-type sound. It is believe that this simple test produced excellent substantiation of the reduction of the so-called "carrier beat" phenomenon by use of *POWER-side* transmission.

By reducing the sensitivity of the AM wave to "Sideband Beating", the widespread implementation of the *POWER-side* system should significantly reduce co-channel interference effects.

POWER-side and Platform Motion

It is important to report that asymmetrical spectrum characteistics of a *POWER-side* wave should reduce one of the basic weaknesses of phase-separated type AM Stereo systems; i.e., the Motorola, Harris and Magnavox systems. (Not the Kahn/Hazeltine ISB AM Stereo system, which is properly classified as a frequency-separated system and which does not suffer from such problems.) Phase-separated type AM stereo systems can, under certain conditions, produce a serious form of stereo image distortion which the author has called "Platform Motion". "Platform Motion" may be defined as the undesirable motion of a stereo image back and forth between the left and right sides.

(The significance of "Platform Motion" cannot be exaggerated and it is indeed the main reason why all stereo receivers designed to receive phase-separated type AM stereo signals must incorporate protection circuitry to switch to monophonic reception under adverse reception conditions. Conversely, receivers designed to receive AM Kahn/Hazeltine system stereo signals, which are free of "Platform Motion", can remain in the full stereo mode under all conditions of reception, insuring stereo coverage equal to the monophonic coverage of the station.)

Platform Motion is created by two main mechanisms:

1) **Multi-path transmission.** In this case, the desired signal reaches the receiver via two paths, such as reradiation from buildings and power lines or from close-in skywave/groundwave paths. (Such groundwave/skywave paths have been reported as close in as a few miles from the transmitter, severely limiting the stereo coverage of the station.) This type of interference causes the desired audio signal to move and is the most serious form of Platform Motion. It can be called "Strong Platform Motion".

2) **From co-channel interference.** In this case, the interference appears to swing back and forth from left to right and can be called "Weak Platform Motion". The net result is a substantial increase in the effect of the interference, because the interference "waves" at the listener.

If the co-channel interfering station operates with *POWER-side*, this second type of stereo image distortion, i.e., "Weak Platform Motion" can be significantly reduced by the interfering station transmitting a *POWER-side* signal instead of a conventional AM signal.

By reducing the sensitivity of the equal sideband AM wave to the phase relationship between the carrier and the sidebands, one type "Platform Motion" should be significantly reduced[7]. The type reduced may be called "Weak Platform Motion" because it is a less important type of platform motion and is created by weak co-channel interference. (See Appendix B.)

Unfortunately, the widely reported close-in skywave/groundwave platform motion, and other "Strong Platform Motion" effects due to power-line and building reradiation, are not alleviated because *POWER-side* is not compatible with phase-separated type AM Stereo systems. Thus, radios designed to receive phase-separated type AM stereo signals will still require protection circuitry to disable stereo reception in less than good reception conditions.

Adjacent Channel Interference

Obviously any modulation procedure has to be evaluated as to its impact on the interference it causes to other stations and also how sensitive the system is to interference from other stations.

It has been pointed out above that substantial advantages accrue to listeners of *POWER-side* stations, whether the station is subjected to co- or adjacent-channel interference. Furthermore, it is shown elsewhere in this paper that *POWER-side* stations are good co-channel neighbors, in that the *POWER-side* wave dramatically reduces co-channel "beat" interference.

Now the question is: what does *POWER-side* operation do to adjacent channel neighbors? Since one sideband is made stronger than the sideband of a normal double-sideband AM wave and the other side is made weaker, one might expect increased interference to neighbors on the strong side of the channel and a reduction of interference to neighbors on the weak side.

Actually, neither sideband of a *POWER-side* signal increases adjacent channel interference. Indeed, stations on both sides, in comparison with normal AM Stereo operation or even normal mono operation, should experience, in practical situations, an improvement in interference. Why this is true can be seen by considering the following:

1) Treating first the extreme case of compliance with occupied-bandwidth rules when only one sideband of the Kahn/Hazeltine AM Stereo wave is used to provide full modulation. This situation goes far beyond *POWER-side* operation in that under worst-case conditions, only 85% of the modulation is in the strong sideband and the remaining 15% is in the weaker sideband. Measurements now on file at the FCC[8] for +125% modulation and −100% single-tone tests covering the range of 100 Hz to 15,000 Hz show that the wave fully complies with Section 73.44 of the FCC rules and regulations. These rules were achieved because the ISB form of AM Stereo is a compact wave (indeed Magnavox, in a forthright report to the FCC, rated this system best in terms of interference production), and the new STR-84 AM Stereo exciter incorporates a sharp filter which eliminates L–R products beyond 7.5 kHz while maintaining L+R response to 15 kHz.

Since the audio processing for *POWER-side* significantly reduces the strength of the stronger sideband over these severe L only, or R only, stereo tests, *POWER-side* fully complies with FCC rules and regulations.

2) The stronger sideband of the *POWER-side* wave is not pre-emphasized. Since pre-emphasis can increase splatter by as much as 10 to 15 db at 10 kHz, this elimination of pre-emphasis on the strong sideband is a significant factor.

3) As mentioned above, the *POWER-side* effect is eliminated at 7.5 kHz by the action of filters in the stereo exciter. Actually, the additional pre-emphasis on the weak sideband causes the weaker sideband to achieve level equality with the stronger sideband at approximately 5 kHz. Thus the impact of *POWER-side*, in terms of causing adjacent channel interference, is restricted to sideband components within ±5 kHz of the carrier.

4) A *POWER-side* signal requires less pre-emphasis because the *POWER-side* wave is less sensitive to loss of modulation caused by phase distortion. The typical RF and IF selectivity characteristic of an inexpensive receiver introduces substantial phase distortion. Therefore, in order to achieve a reasonable brightness of sound quality an equal-sideband AM wave requires substantially more pre-emphasis than does a *POWER-side* wave. Since the amount of pre-emphasis used directly increases splatter interference, a *POWER-side* signal, for a given brightness of sound, should produce substantially less adjacent channel interference.

As an example, if the phase distortion of the overall sytem, including the transmitting antenna, receiving antenna, and the RF and IF selectivity circuits in the receiver, create a phase distortion of 60 degrees at say 6 kHz (12 kHz IF bandwidth), a conventional AM wave will have 25% efficiency in terms of sideband power utilization. Under the same conditions, a *POWER-side* wave provides approximately 64% efficiency. In other words the effective modulation of the conventional AM wave is 50% and the effective modulation of the *POWER-side* wave is 79.9%.

5) There is also a practical consideration that should substantially reduce adjacent channel interference when broadcasters implement *POWER-side*. This may be seen by recognizing the fact that *POWER-side* stations derive a substantial portion of the system's advantages because listeners can "sideband tune" their radios. "Sideband Tuning" advantages are a function of the amount of off-tuning listeners find advantageous. Thus, the "cleaner" the *POWER-side* signal, the greater the "sideband tuning" advantages.

In other words, a broadcaster that uses the *POWER-side* system will find it important to produce an extremely clean wave that will not "splatter" on the station's own listeners. This means *POWER-side* stations will eschew bad practices like negative overmodulation, using improperly neutralized transmitters, operating with excessive pre-emphasis, etc. Recent tests[9] conducted by adjacent channel neighbors in California, KMNY 1600 kHz and KDAY 1580 kHz Los Angeles, lend support to the fact that *POWER-side* reduces adjacent channel interference.

CONCLUSIONS

It is shown herein that the *POWER-side* system significantly improves monophonic reception using existing Independent-Sideband AM Stereo transmission equipment.

It is also shown that there should be significant reduction of both co- and adjacent-channel interference caused by *POWER-side* signals.

A number of on-the-air evaluations of the system support the results of the above analysis, including the reduction of selective fading and reduction of co- and adjacent-channel interference effects.

The advantages of the system were separated into two types: one group applicable only to mono receivers capable of "Sideband Tuning"; and a second group of advantages that are available to all types of receivers, including carrier or center-tuned mono and stereo radios.

APPENDIX A

Analysis of Co-Channel "Sideband Beat"

The amplitude of the "Sideband Beat" of a co-channel interfering signal is a function of the relative amplitudes of the interfering wave and the desired wave. Under practical operating conditions, the desired signal is at least 20 db greater than the interferring co-channel wave. Accordingly, the envelope-detector performance closely approximates the performance of a product-type detector in that the strong local carrier controls the "switching function" of the envelope detector. (Communication engineers will recognize the similarity of this operation to "exalted carrier" detection which was used in early short wave SSB receivers.)

As pointed out above, the phase of the local carrier, relative to the interfering carrier, is a function of time, and under typical conditions the angle between the two carriers is an unbiased random function, i.e., a rectangular density function.

When there is a specific frequency difference between the two carriers; for example, a 1 Hz error, the beat frequency will equal 2 Hz (two times the carrier difference frequency[10]), ±two times the random frequency errors that would even apply to a phase-locked "synchronous" stations. Such random frequency errors are functions of propagation characteristics, receiver location, etc.

As mentioned above, the most important phenomenon in terms of co-channel interference is the dramatic variation in audio level of the undesired signal as the angle between the two carriers swing over a cycle. When this angle reaches 90 degrees, or any other odd multiple of 90 degrees, the amplitude of the fundamental Fourier component is nulled, leaving a slight amount of second harmonic distortion. (The reason the distortion is small is that the desired carrier causes the envelope detector to approximate the action of a product demodulator, greatly reducing the quadrature distortion effect.)

It is useful to determine the amplitude for the complete range of relative carrier phase between the desired and undesired signals over a 0 to ±90 degree region. (At angles beyond ±90 degrees the amplitude repeats this same shape.)

In the following equations the RF terms, DC terms, and the sub-audible low frequency terms generated by beating the two carrier frequencies are deleted. Thus, the analysis can be restricted to multiplying the local carrier by the two co-channel interference sidebands. It is assumed that the sidebands from the co-channel interfering signal are produced by a single-tone modulation and with a modulation factor of m. It is also assumed that the local station's carrier has an amplitude of K volts and the interfering carrier has an amplitude of unity.

$$e = \underbrace{[1 + m \cos(w_A t)] \times \cos(w_c t)}_{\text{Interference}} \times \underbrace{K \cos(w_c t + \theta)}_{\text{Local Carrier}}$$

Ignoring interfering carrier

$$= [m/2 \times \cos(w_c t + w_A t) + m/2 \times \cos(w_c t - w_A t)] \times K \cos(w_c t + \theta)$$

Using product trigometric identities

$$= K\, m/4 \times \cos(w_A t - \theta) + K\, m/4 \times \cos(2w_c t + w_A t + \theta) + K\, m/4 \times \cos(-w_A t - \theta) + K\, m/4 \times \cos(2w_c t - w_A t + \theta)$$

Considering only audio components

$$e = K\, m/4 \times \cos(w_A t - \theta) + K\, m/4 \times \cos(w_A t + \theta)$$

noting $\cos(\phi) = \cos(+\phi)$

Using the following identity:

$$1/2\, [\cos(A-B) + \cos(A+B)] = \cos A \times \cos B$$

We see that:

$$e = \cos\theta \times K\, m/2 \times \cos(w_A t)$$

Thus, the amplitude of the sideband beat wave follows the absolute value of a cosine wave, which is a well known waveshape in radio engineering; i.e., the output of a resistance-loaded full-wave rectifier.

APPENDIX B

Analysis of "Weak Platform Motion"

FIG. 3

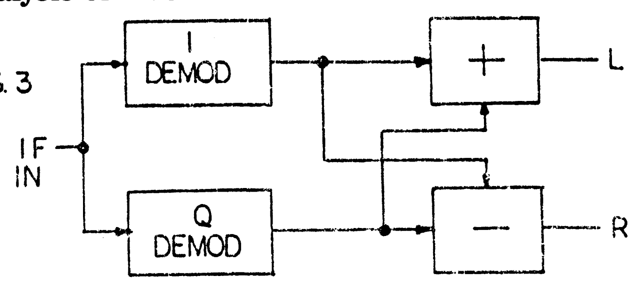


FIG. 3 is a simplified block diagram of a phase separated type AM Stereo decoder. It does not include distortion correction circuitry, as would be required for the Magnavox or Motorola type AM Stereo decoder. (Since the Harris system is a true quadrature system it does not require any distortion correction circuitry.)

Assuming that the receiver is tuned to a strong local signal, which at the insant of analysis is unmodulated, the waveshapes of FIG. 4 show how a conventional AM wave will exhibit severe image notion when demodulated by a phase separated type decoder.

FIG. 4A

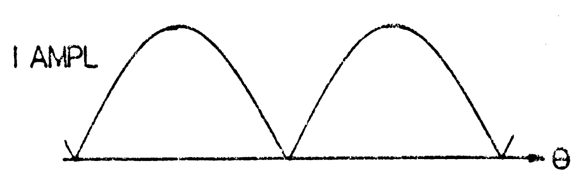


FIG. 4a shows the amplitude of the in-phase audio wave as a function of the phase between the strong local carrier and the weak intefering co-channel carrier. This waveshape has been discussed in Appendix A.

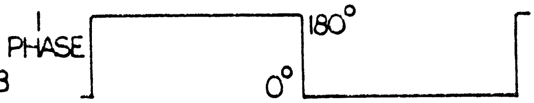


FIG. 4B

FIG. 4b shows the phase of the in-phase component. It is seen that the demodulated audio reverses phase whenever the amplitude function goes through a cusp.

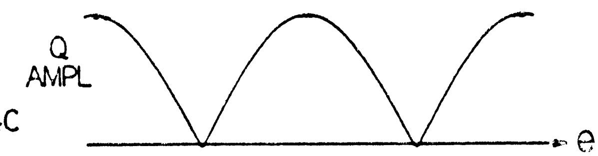


FIG. 4C

FIG. 4c shows the amplitude function of the quadrature component of the incoming interfering wave.

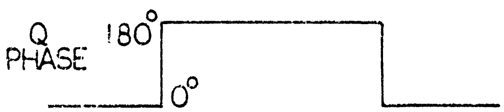


FIG. 4D

FIG. 4d shows the phase function of the quadrature audio wave.

Under normal operating conditions, the outputs of the I and Q detector of FIG. 3 are combined in the sum-and-difference matrix, producing the desired L and R waves. Unfortunately, the interference from the weak co-channel station swings from full left, to center, to full right, as a function of carrier phase. This is shown in FIG. 4e.

IMAGE LOCATION	RIGHT	CENTER	LEFT	CENTER	RIGHT	CENTER	LEFT

FIG. 4E

The reason the wave falls in the center at regular intervals is that at those instances either the I amplitude is zero or the Q amplitude is zero. Under such conditions, since there is only one signal going into the sum-and-difference circuits, the L and R outputs must be equal, causing the image to appear in the center. (When the phase of the L and R outputs are out of phase as they are when the I amplitude is zero, the image will be somewhat strange, as it is with any out-of-phase speaker situation.)

During other conditions of carrier phase, the left and right channels are unequal. Complete separation points will occur when the amplitude of the I wave and the amplitude of the Q waves are equal. In other words, at multiples of 45 degrees between the two carriers the I and Q detector outputs are equal. Since at these instances the I and Q audio signals are either in phase or out of phase, either a full L signal results or a full R.

This simple analysis clearly shows how an interfering co-channel AM wave causes "Weak Platform Motion". Such Platform Motion has been experienced in the field and it results in significantly increased annoyance by causing, in effect, the interference to "wave" at the listener.

Now, let us consider FIG. 5 which shows the phase function of a pure SSB wave. While the *POWER-side* wave is not a pure SSB wave, it should substantially reduce Weak Platform Motion.

In the case of the SSB wave, the amplitude of the I and Q waves are equal under all phase conditions. This is one of the basic reasons why SSB reception is particulary rugged, in terms of providing acceptable performance under disturbed propagation conditions. The phase of the I and Q audio waves linearly swing from −90 degrees to +90 degrees. (This assumes the upper sideband is transmitted. If the lower sideband is transmitted the phase slopes are reversed.)

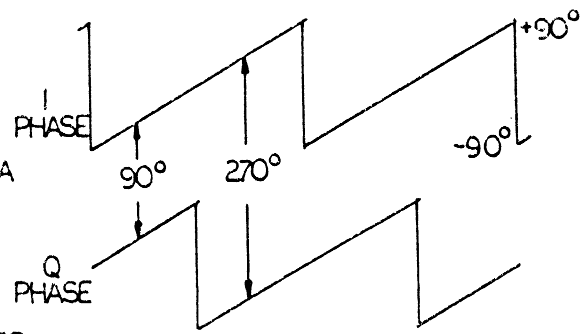


FIG. 5A

FIG. 5B

Examination of FIGS. 5A and 5B shows the phase difference between the I and Q audio waves is either 90 or 270 degrees. This cases the L and R outputs of FIG. 3 to be equal because the I and Q waves are equal in amplitude and are in quardrature. Thus, under all conditions of relative carrier phase, the L and R waves are equal and the interference will remain in the center, eliminating this one form of Platform Motion.

Unfortunately, the more serious "Strong Platform Motion" is caused by self interference, and there is no apparent mechanism for removing it.

NOTES

1 Leonard R. Kahn, *Compatible Single-Sideband,* Proc. IRE, Vol. 49, No. 10, pp 1503-1527. Also see earlier forms of sideband broadcasting: N. Koomans *Asymmetrical sideband Broadcasting,* Proc. IRE, Vol. 27, pp 687-690, and P.P. Eckersly *Asymmetrical-sideband Broadcasting,* Proc. IRE Vol. 16, pp 1041-1092.

2 Private communication from Dennis R. Ciapura, Vice President, Noble Broadcasting Co. to Leonard R. Kahn, describing special stereo processing used by the recording industry.

3 Leonard R. Kahn, *Amplitude Modulation Theory and Measurements - New and Old Paradoxes,* Proc. 41st NAB Annual Broadcast Engineering Conf. 1987.

4 Synchronous demodulators multiply the carrier components by the sidebands; they also have been called "product demodulators" and "exalted carrier detectors". Synchronous demodulators do, however, eliminate the distortion of an envelope detector when detecting a conventional AM wave suffering from selective phase distortion.

5 Experimental verification first obtained by radio station KSL - Bonneville, engineering department.

6 Experimental verification obtained by radio station WELI - Clear Channel engineering department.

7 The author points out that while there has been no experimental verification, the analysis indicates that there should be some reduction of "Weak Platform Motion." Recognizing the commercial importance of this matter, it is believed that early publication of this particular facet of the *POWER-side* system, absent experimental proof, is justified. The author plans to write a further article covering these effects as well as information concerning methods for enhancing stereo effects when *POWER-side* signals are received with Kahn/Hazeltine type AM stereo radios.

8 D.L. Bordonaro, *WFTQ Occupied Spectrum Kahn STR-84,* dated February 26, 1986.

9 Private communication between Mr. Andy Laird, Vice President of Engineering for Heritage Media Corporation (KDAY), and Leonard R. Kahn.

10 The reason for the doubling of the error Δ F is that the carrier error displaces the audio from one sideband by $+\Delta$ F, and the audio from the other sideband aurio by $-\Delta$ F, making the difference between the two audio waves 2 Δ F.

RADIO CLUB OF AMERICA PROFESSIONAL DIRECTORY

GAETANO (TOM) AMOSCATO
Communications Consultant
150-47A 12th Road
Whitestone, NY 11357
718-767-7500

GARY EISENBERG, WB2EQX
Communications Through 2-way Radio
460 West 35th Street
New York, NY 10001
212-736-6500

ROBERT I. ELMS, P.E.
Land Mobile & Telemetry Consulting Engineer
72 Smithtown Road
Budd Lake, NJ 07828
201-691-9067

WILLIAM F. ENDRES
Television Security Systems
145 Main Avenue
Clifton, NJ 07014
201-473-8822

ERO E. ERICKSON
Business Radio Comm. Consultant
5622 West Diversey
Chicago, IL 60639
312-889-7654

R. JAMES EVANS
Comms. Consultant, Land Mobile
2803 Southwood Drive
East Lansing, MI 48823
517-351-3252

W.G.H. FINCH, P.E.
Fax and Record Communications
3025 Morningside Blvd.
Port St. Lucie, FL 33452
407-335-5147

MILTON R. FRIEDBERG
Management Consultant
2537 Claver Road
Cleveland, OH 44118
216-382-4070

HARRY S. GARTSMAN, W6ATC
Military Avionics Systems Consultant
9921 Sunset Blvd.
Beverly Hills, CA 90210
213-273-1995

ALAN W. HALEY
Land Mobile Consultant
319 Tacoma Ave., N.#608
Tacoma, WA 98403
206-272-8310

CHARLES HIGGINBOTHAM
Land Mobile Consultant
85 Aspen Meadows Circle
Santa Rosa, AC 95409
707-539-8638

JACK HOFELD
Communications Consultant
P.O. Box 422
Virginia City, NV 89440
702-847-0723

R.W. JOHNSON, P.E., W6MUR
FCC/VDE RFI Measurements
2820 Grant Street
Concord, CA 94520
415-687-7620

LEONARD R. KAHN
Communications Consultant
425 Merrick Avenue
Westbury, NY 11590
516-222-2221

JOEL I. KANDEL, KI4T
Communications Consultant
5463 SW 92 Avenue
Miami, FL 33165
305-596-9373

BRUCE M. KARR, KA4MET
Public Safety Communications Consultant
4727 E. Alamos, #116
Fresno, CA 93726
209-292-2024

JAMES A. LANG, P.E.
Telecommunications Consultant
24591 Summerhill Court
Los Altos, CA 94022
415-948-5914

FRED M. LINK
Communications Consultant
Robin Hill
Pittstown, NJ 08867
201-735-8310

LOREN McQUEEN
Communications Consultant
2633 South Bascom Avenue
Campbell, CA 95008
408-377-2900
TELEX 346354 (C AND C CMPL.)

JAMES MANN
P.O. Box 340
Agoura, CA 91301
818-889-6666

STUART MEYER, W2GHK
Land-Mobile Radio Consultant
2417 Newton Street
Vienna, VA 22180
703-281-3806

RAY MINICHELLO, P.E.
Communications Consultant
33 West Water Street
Wakefield, MA 01880
617-245-4640
800-225-4438

JACK REICHLER
Antenna Sites So. California
23501 Park Sorrento #213A
Calabasas Park, CA 91302
818-888-7000

JOHN J. RENNER
Advanced Technology
3426 North Washington Blvd.
Arlington, VA 22201
703-525-2664

THOEDORE P. RYKALA, P.E.
Communications Consultants
33247 Cloverdale
Farmington Hills, MI 48024
313-478-6994

ROBERT G. SCHIED
Government Marketing and Cellular Consulting
5900 Princes Garden Parkway #105
Lanham, Maryland 20706
301-352-4484

F.H. SHEPARD, JR., P.E.
Consulting Engineer
16 Lee Lane, Countryside
Summit, NJ 07901
201-273-5255

CARL E. SMITH, P.E.
Communications Consultant
8200 Snowville Road
Cleveland, OH 44141
216-526-4386

JAMES L. STEVENSON, NCE, IEEE
Communications Consulting Engineer
P.O. Box 340
North Branch, MI 48461-0340
(313) 688-2633

ERIC D. STOLL, Ph.D., P.E.
Communications Consultant
117 Hillside Avenue
Teaneck, NJ 07666
201-836-2351

DAVID TALLEY, W2PF
Telecommunications Consultant
10275 Collins Avenue, Suite 1533-S
Bal Harbour, FL 33154
305-868-4131

RAYMOND C. TROTT, P.E.
Land Moble/Microwave Communications Consultant
1425 Greenway Drive #350
Irving, TX 75038
214-580-1911

WOULD YOU LIKE TO BE INCLUDED IN THE PROFESSIONAL LISTING?
Contact STUART MEYER
2417 Newton Street
Vienna, VA 22180
703-281-3806

T-4 CHRONOGRAPH

by Frederick G. Suffield, P.E. (M 1978, S 1984)

During 1944, the U.S. Navy became concerned with the problem of overranging by the large-calibre guns aboard battleships and heavy cruisers. With good radar-range to targets, shells went beyond distant-ship targets far too frequently. Several organizations were asked to look into the problem for the Navy.

Some initial work by members of the Westinghouse Electric Company's Research Laboratory led to the conclusion that the muzzle velocity was a parameter to examine. Range varies approximately as the square of the muzzle velocity; thus it is a critical element of the range equation.

Firing tables for large-calibre guns were derived by firing the barrels at the Dahlgren Proving Ground with a controlled lot of powder, and carefully weighed and balanced sand-loaded shells. From measured velocity, firing tables were calculated for each barrel. At the proving grounds, velocity was measured by firing the magnetized shell through two large coils of wire suspended close to the muzzle, but separated by several feet, and timing the shell passage over the distance between the rings. The time-measurement system was not as accurate as desired; wind varied the coil spacing and the velocity was not true muzzle velocity.

To recalibrate the guns on a major battleship of the U.S.S. Iowa class would mean removing the ship from combat, going to one of very few yards where a 200 ton barrel could be removed, transporting the barrel to Dahlgren for recalibration, and returning it to the ship. In the wartime period, this was not possible.

If the muzzle velocity using a known lot of powder and controlled shells could be measured onboard ship, the firing table for the barrel could then be updated.

Several groups considered various ways to accurately measure the velocity onboard a ship. One method was to use a polarized transmitter in the shell, receive the signal and plot the nulls as the shell rotated. Another was to paint shells with white-and-black portions and photographically derive velocity.

The Westinghouse team decided that by reflecting a continuous-wave microwave signal off of the base of the shell, comparing this with the transmitted frequency and measuring the difference of frequencies (the Doppler shift), one would have a high accuracy measurement of shell velocity.

A breadboard system was built and tested at the Aberdeen Proving Grounds, and at Dahlgren, and data were obtained to an accuracy of 0.1% of velocity.

The Navy contracted for the building of 17 units called the T-4 Velocity Chronograph. A few were to go to the British, some to the Army, the rest to the Navy. Within a few months the original laboratory model and Serial #1 were ready for field testing.

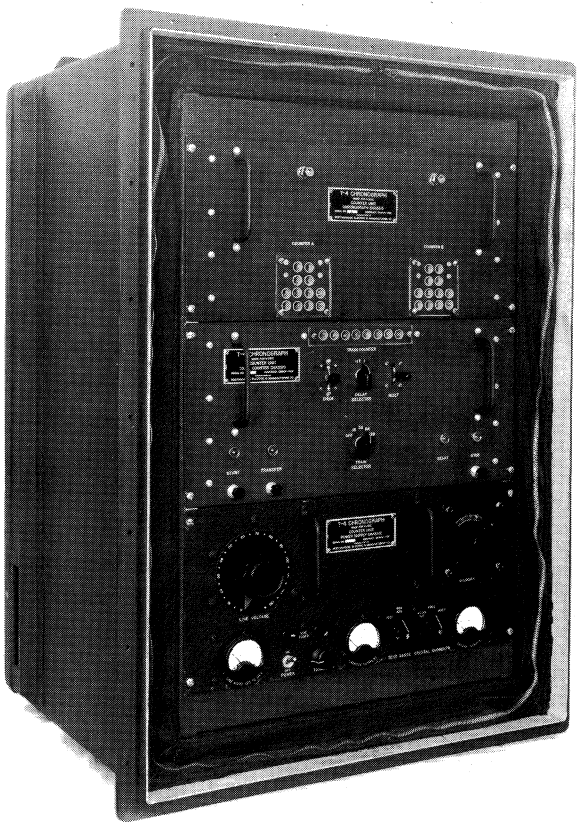
The two equipments were taken to Dahlgren, and checked out. As the Navy had elected to conduct the field test on the battleship U.S.S. Iowa, BB-61, in the Pacific, thirty rounds of sand-loaded 16" shells were weighed and balanced, and thirty rounds of powder from the same lot were bagged (50 lbs. per bag, six bags for each round fired), and the ammunition shipped aboard a special train to Long Beach, California. The Iowa was recalled from the Pacific to the Long Beach harbor, and a few days before the ship and the ammunition load converged on Long Beach, the Navy flew the Westinghouse engineers and the equipment from Dahlgren to Long Beach.

At sea, after the powder had temperature stablized in the powder magazine (necessary since the velocity varies with powder temperature) and after set up of the equipment, a destroyer escort towed a target and the target range was measured by all radars available, and that range was inputted to the fire control system.

The thirty rounds were fired, with the splash point and muzzle velocity recorded for each round.

Reduction of the data indicated muzzle velocities well over those anticipated but with small round-to-round variations. True range was commensurate with the true, measured velocity.

The Doppler system made use of a 723 A/B (2K25) X-band Klystron for the transmitter. The 1/4 watt output was adequate for the range required. Two 18" paraboloidal reflectors and feeds were mounted side by side; the feeds coupled together behind the reflector with waveguide. The Klystron was mounted on the waveguide to drive the transmit antenna. Separating it from the receiving antenna was a window with adjustable-screw short to allow a small amount of RF to leak across to the receiver side. On the receiver side, was located a IN23-B crystal for detection.



Control Unit including power supply, amplifiers, and counters.

Since velocity was measured in feet-per-second, it was desired that the microwave frequency be adjusted to a value that was easily converable to feet, and the Klystron was tuned to a frequency to be 1.26" free space wavelength. To eliminate complex automatic frequency control, a standard X-band TR cavity was used with added windows to increase the Q, fed from the Klystron side of the waveguide, and with a crystal and meter on the output. Thus one had a quite accurate, tuneable, portable, frequency reference.

The detector crystal output-frequency was in the range of 10 to 60 KHz for the range of shell velocities to be measured. This low-level signal had to be amplified to feed the frequency counter but the noise bandwidth was unacceptable. In that one knew the approximate velocity to be measured, a tuned circuit was added to the input of the wide-band amplifier, with the tuning dial calibrated in feet per second.

In 1944, there were no frequency counters, and the measurement at the Doppler frequency under field conditions was a challenge. Vacuum-tube binary counter circuits were available, but limited in the speed or frequency limit of counting. Displays were typical binary; each decade read 1,2,4,8. The solution rested upon defining an accurate time base, for which a 400 KHz crystal would give 2.5 microsecond intervals which was about the limit of the counter speed.

The Doppler difference frequency was amplified and divided into two channels. One channel was called the Train Count, and was selected to count 64, 128, 256 or 512 cycles of the incoming frequency. The other channel opened a gate circuit at the start of the selected count and closed it at the end.

The gate admitted the 400 KHz signal to a second counter called the Time Counter, and read out the number of 400 KHz cycles occurring during the time period of the selected train count. Thus, as an example, one had — for 128 cycles of the unknown Doppler — the number of 400 KHz cycles occuring during the 128 cycles. This was equivalent to 128/time, reducing to a single cycle the unknown frequency divided by the time intervals of 2.5 microsecond cycles, thus $1/T = f$, the unknown frequency.

Refinements recognized that as the shell moved into the field of view of the antenna, the signal would increase above the noise level with a probability of the earliest counts being missed. Therefore, a selectable delay was added to allow 16, 32, or 64 counts to be rejected before the time gate was opened. This had a secondary benefit, for two type of powder were in use on board ships. Smokeless powder, generally white smoke, was used for daytime; flashless powder, black smoke, for night firings. However the highly-visible flash of smokeless powder also ionized air and blanked-out the signal for a short distance; thus the delay was neccesary.

The results of the field tests were of definite value to the Navy. The generation of the firing tables takes into account many variables. One of these is the bore erosion: the gradual increase in bore diameter due to the hot gas, powder particle passage, shell passage, condition of the bore, characteristics of the steel in the liner, and other variables. In general, history had led to the factors used in the firing table computational work. However, it appeared that much of the historical data was based upon WWI experience in long-range combat between capital ships.

World War II saw much use of large calibre guns for shore bombardment in support of landings.

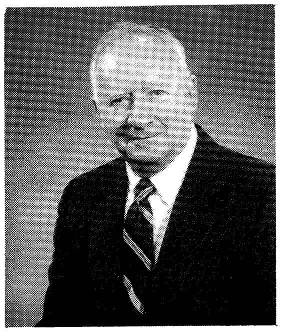
Several loadings of powder are used to establish the muzzle velocity; and "target" loadings of lower velocity frequently were used for shore bombardment. Reducing muzzle velocity from 3200 to 2400 feet per second results in an appreciable reduction in bore erosion, and those lower velocities had not been adequately factored with the firing table calculations. Thus the bores were tighter than anticipated, muzzle velocities were higher than anticipated, and the shell traveled further than desired.

Other data derived from the T-4 Ballistic Chronograph were of benefit to the Ordnance people. An element of important in powder formulation is the burning rate and breech pressure. The safety of the gun, and the obtaining of consistent and optimum velocity from a given weight of shell and powder type, is a critical element in design. By positioning the Chronograph antennas in a field out in front of a gun and firing over or slightly to one side, and feeding the Doppler output to a recording oscillograph, one was able to record the rate of acceleration within the barrel, the change in acceleration from the muzzle outward, and the spin variation as well as yaw of the round.

The successful test led to an interest by the Navy in installing an on-board system on all major ships so that firing tables and gun barrel characteristics could be continually matched.

The field tests had shown some interference from "X" band radars on board the ship. Since but few "K" band systems were in use, and atmospheric absorption would help reduce interference, it was felt that "K" band frequencies would be the optimum to use. However, the war came to an end before further work could be done, and the project was terminated.

HONORS AND AWARDS 1988

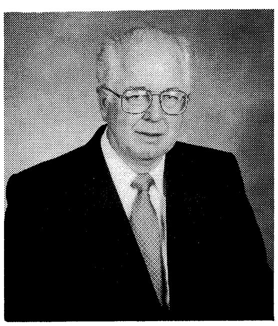


ARMSTRONG MEDAL
Luther G. Schimpf

Awarded in recognition of his inventions which were fundamental to the development and application of digital transmission, spread spectrum, and frequency-band compression.

SARNOFF CITATION
Mal Gurian

Awarded in recognition of his advancement of electronic communications, and contributions to the radio industry.

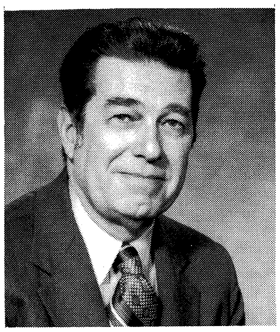


BUSIGNIES MEMORIAL AWARD
Francis T. Cassidy

Awarded in recognition of his work in the advancement of electronics for the benefit of mankind.

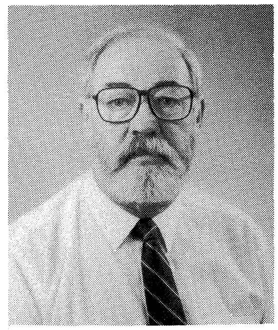
LEE deFOREST AWARD
Fred M. Link

Awarded in recognition of his early work with Dr. Lee deForest.



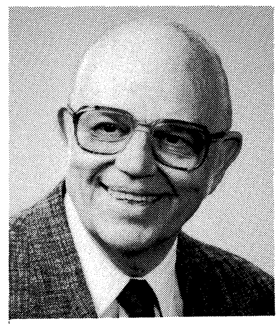
FRED M. LINK AWARD
Stuart F. Meyer

Awarded in recognition of his contributions to the development of land mobile radio communications.



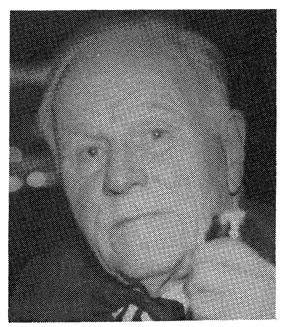
ALLEN B. DuMONT CITATION
William D. Kelly

Awarded for his role in pioneering the installation of DuMont TV transmitters and assisting the FCC in establishing standards for TV transmitter operations.



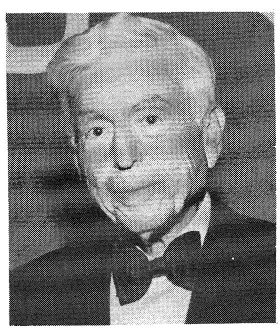
RALPH BATCHER MEMORIAL AWARD
Dr. Ralph W. Muchow

Awarded for his distinguished work in collecting, maintaining and exhibiting early radio transmitters and receivers.



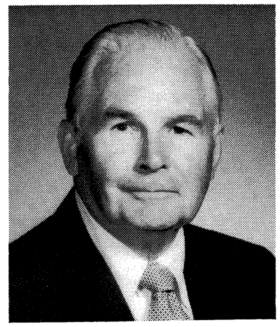
PIONEER CITATION
Francis H. Shepard, Jr.

Awarded for his pioneer inventions and patents in radio communications, computers and electronic circuitry.



PRESIDENT'S AWARD
David Talley

Awarded for his initiative in the formation and for his continuing high level of activity with the Florida Section of The Radio Club of America.



SPECIAL SERVICES AWARD
Jerry S. Stover

Awarded for his outstanding support and distinguished services to The Radio Club of America.

FELLOWS - 1988

The following members are elevated to the Grade of Fellow in The Radio Club of America in recognition of their achievements in furthering the goals of the Club, and are here Cited:

Ms. Minnie M. Adams, Vice President — Mitchell Energy & Development Corp., The Woodlands, TX, and Chairperson of NABER, for leadership in mobile communications industry.

Hugh G.J. Aitken, Ph.D., Professor — Amherst College, Amherst, MA, for distinguished contributions in the field of history of radio and electronics.

Don Bishop, Editorial Director — *Mobile Radio Technology,* Overland Park, KS, for achievements in the fields of publishing and radio broadcasting.

John E. Brennan, President and COO — Metro Mobile CTS, Inc., New York, NY, for leadership in developing specialized mobile and cellular radio telephone communications.

George K. Burton (deceased), retired Captain of Contra Costa County (California) communications system, for pioneering work in developing mobile-radio repeater systems.

Ms. Connie M. Conte, Assistant to the President - Tele-Measurements, Inc., Clifton, NJ, for dedicated services to The Radio Club of America and for successfully coordinating the annual Awards Dinners of the Club.

Robert I. Elms, P.E., retired Consulting Engineering, Budd Lake, NJ, for contributions in command and control systems for nuclear weapon systems and radiation safety hazards abatement.

Ms. Jacqueline H. Ericksen, Ph.D., Vice President — All-Comm, Inc., Albuquerque, NM, for contributions in managing mountain-top repeater sites to minimize interference and improve technical operations.

Earl H. Flath, Jr., P.E., Consulting Engineer — Dallas, TX, for contributions in developing computer prediction systems, integrated antenna systems for missiles and aircraft, and special radars.

Lloyd A. French, retired Executive and Educator — Sacramento, CA, for leadership in APCO activities and in organizing technical training programs in mobile radio communications.

John R. Galanti, Vice President, Network Engineering of Bell Atlantic Mobile Systems — Basking Ridge, NJ, for leadership in technical development and advancement of the cellular radio telephone industry.

Scott J. Goldman, President — The Goldman Group, Los Angeles, CA, for contributions in engineering analysis and research design in cellular radio and paging implementation.

George D. Graul, retired Police Communications Engineer — Jersey City, NJ, for leadership in IEEE activities and in community repeater operations.

Arthur L. Greenberg, retired Executive — Wading River, NY, for pioneering work in Amateur radio organizations and developments in antennas.

Ralph A. Haller, Chief: Private Radio Bureau, FCC — Washington, DC, for leadership in deregulation of radio communication services, and in testing and measurement technologies.

Homer H. Harris, CEO of Industrial Communications Systems, Inc. — Aguanga, CA, for pioneering work in radio common carrier and paging services, and leadership in the radio communications industry.

Norman D. Hawkins, President of E.F. Johnson Canada Inc. — Scarborough, Ont., Canada, for innovative activities in promoting the use of mobile radio communications equipments.

Gerald M. Howard, Esq., P.E., retired engineer and attorney — Dallas, TX, for pioneering work in geophysical prospecting for oil, in radio broadcasting, and as an FCC attorney.

Jay R. Huckabee, Consultant to Jay Huckabee Company (electronics distributor) — Snyder, TX, for pioneering work with FCC Radio Intelligence Division, and Naval Research Laboratory.

William O. Hunt, former Chairman and CEO of Alliance Telecommnications Corp., Dallas, TX, for industry leadership in the fields of radio common carrier, paging, and specialized radio communication services.

Frank H. Jarvis, retired Military Communications Executive, New York Telephone Company — Longboat Key, FL, for responsibilities relating to communications for the President of the United States.

Ms. Antoinette P. Kaiser, President & CEO of Sti-Co Industries, Inc. — Buffalo, NY, for leadership in the design and manufacturing of specialized antennas for mobile radio communications.

John A. Linton, Jr., Manager of Administrative Services, B.F. Goodrich Co. — Akron, OH, for contributions to the extended use of land mobile radio communications.

Ake Lennart Lundqvist, President of Ericsson Radio Systems AB — Stockholm, Sweden, for industry leadership and major contributions in mobile radiotelephony.

Joseph F. Marshall, P.E., retired Engineer, FCC — Hyattsville, MD, for contributions in spectrum engineering studies and developments of new radio technologies.

J. William Miller, Engineering Consultant — Fairfax Station, VA, for contributions in the fields of microwave, tropospheric scatter and ionospheric scatter propagation, and in HF, VHF, and UHF communications.

Harry J. Mills, retired Engineer, RCA Service Company — Hendersonville, NC, for responsible management of engineers assigned to support NATO military operations, and for research on communication antennas.

Clive H.K. Moffat, Product Group Manager of Philips Radio Communication Systems Ltd. — Cambridge, England, for contributions to the international development of mobile radio equipments and services.

Anthony Natole, Vice President of AMTOL Radio Communications Systems, Inc., — Whitestone, NY, for contributions and leadership in the design, installation and servicing of land-mobile radio systems.

John S. Sawvel, Jr., Projects Engineer of Ohio Edison Company — Akron, OH, for management of private telecommunications systems utilizing data transmissions, point-to-point and land mobile radio.

Harry L. Schmidt, Director of Overseas Engineering for Micro Byte Research Inc. — Scarborough, Ont., Canada, for contributions in the design of advanced audio products and voice recognition systems.

Herschel Shosteck, Ph.D., President of Herschel Shosteck Associates Ltd. — Silver Spring, MD, for penetrating economic analyses of the mass telecommunications field and, particularly, cellular telephony.

Ms. Ethel M. Smith, retired from U.S. Navy Scientific & Technical Processing Center — Washington, DC, for distinguished service in electronic intelligence and cryptology.

Gene F. Smith, Vice President & General Manager of Mobile Radio Dispatch Service, Inc. — East Brunswick, NJ, for pioneering radio common carrier and paging services.

George W. Weimer, P.E., Vice President of Engineering of Raymond C. Trott Consulting Engineers Inc. — Irving, TX, for contributions in microwave and mobile-radio data systems, and simulcasting.

NEW DESIGN AND CONSTRUCTION DATA FOR VERTICAL ANTENNAS

by Arch Doty (M 1972,F 1984,L 1985)
Harry Mills (M 1983,S 1987,F 1988)

ARCH DOTY

HARRY MILLS

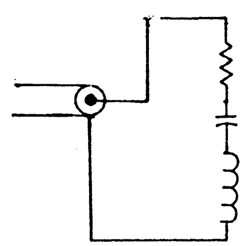
This article contains excerpts from the two papers presented by Messrs. Doty and Mills at the Radio Club of America Technical Symposium on November 20, 1987. The full text of these papers will be published by the American Radio Relay League in ***The ARRL ANTENNA Compendium, Volume 2.***

Of interest is the fact that this article is the first in Club history that has been prepared on a home personal computer, and provided in "camera ready" form for publishing. For the information of computer buffs, this was accomplished by Arch Doty (Chairman of the Club's Computer Committee) using a Tandy 1000TX computer, WordPerfect 5.0 software and a Hewlett-Packard DeskJet printer.

(Ed. note)

I. DIMENSIONS OF 1/4 WAVELENGTH MONOPOLE ANTENNAS

Vertical antennas are not too complicated. They may be drawn, looking from the feed point, as a series resistor, series inductor and series capacitor:



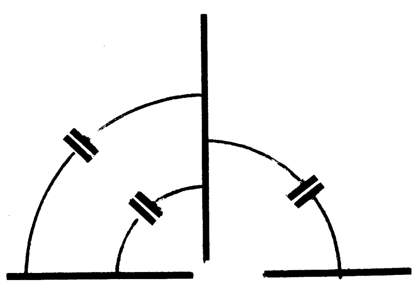
Where: The RESISTOR represents the several resistances inherent in an antenna, including the ohmic resistance value of the metallic antenna element, the "radiation resistance" of the antenna, etc;

: The INDUCTOR is the self inductance of the wire or tubing used as the radiating element; and

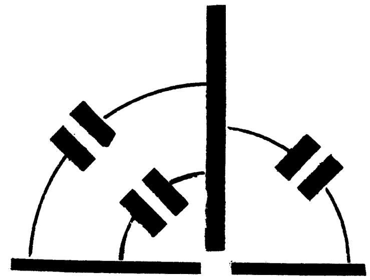
: The CAPACITOR is the capacity between the radiating element and the ground or surrounding objects.

The resonant frequency of a vertical is "A frequency at which the input impedance of an antenna is nonreactive" <1>. In other words, when the inductive reactance of the radiating element is exactly balanced by the capacitive reactance of the antenna system at a certain frequency the antenna is resonant at that frequency.

To give an example of how this works, let's first look at a resonant vertical antenna. The vertical radiating element has a certain natural value of inductive reactance. This value is balanced, at resonance, by the capacitive reactance resulting from the adjacency of the radiating element to ground, or to nearby structures (as, perhaps, a base insulator). For illustrative purposes this capacity may be imagined as resulting from a lot of small capacitors- each having one end attached to the antenna, and the other end attached to the ground:



If the diameter of the radiator is increased, this increases the surface area of the element that is "looking" at the ground. Thus the element will have greater capacity to ground- just as making capacitor plates larger increases their capacity:



HEIGHT TO DIAMETER RATIO

If the second antenna shown above, with the larger diameter element, is to remain resonant at the original frequency, it must be shortened enough so that it once again provides the same capacity to ground as did the original radiator. This is referred to as the "Height (or Length) to Diameter Ratio", or the "Antenna to Diameter" effect on the resonant frequency of a vertical antenna: the "fatter" a radiating element, the shorter it must be to maintain a fixed resonant frequency.

This explains why the physical height of a "1/4 wavelength" vertical antenna may be considerably less that an electrical quarter wavelength.

END EFFECT

There is a second phenomenon, referred to as "End Effect" that also results in the physical length of a radiator being shorter that the electrical length.

End effect results from the "boundary condition" at the end(s) of the radiator, i.e., where the metallic element ends, and a non-conducting medium begins (as, air, or an insulator). In this area there is a concentration of electric lines of force, which implies a greater capacitance per unit length than is found along the rest of the radiator.

The result of this "extra capacity" at the end of an element is to "load" the element and thus reduce its resonant frequency. Thus it will be necessary to reduce the physical length of the element to maintain its original resonant frequency.

In summary, anything that adds capacity to a vertical antenna must be recognized when deriving a formula for the physical length of the radiating element.

FORMULA FOR THE HEIGHT OF 1/4 WAVELENGTH VERTICAL MONOPOLES

One of the objectives of the test series was to derive a formula that would allow determination of correct antenna heights for vertical monopoles having various diameters.

A review of the literature showed that the data provided on this subject in many of the most popular references was not correct, as they did not make compensation for one or more of the factors described above. Thus use of this data will provide incorrect vertical antenna heights.

The importance of considering all of these factors is illustrated by the fact that a variation of 5" was found between the element heights necessary to resonate the thinnest (1/8") and the thickest (2") elements at the same frequency (29.0 MHz.).

With the above in mind, the following formula was derived:

$$\text{HEIGHT OF A 1/4 WAVELENGTH VERTICAL MONOPOLE (in feet)} = \frac{246\,C}{f(\text{MHz.})}$$

Where C = A factor to compensate for ALL aspects of the antenna system that cause the physical height of the radiating element to be less that its electrical length (as, Height to Diameter Ratio, End Effect, etc.)

In order to determine the "C" factor, several thousand measurements were made of vertical monopole antennas located above the center of a 20' x 20' counterpoise incorporating 64 radial wires raised 5' above the ground. A peripheral wire connected the ends of the radials to eliminate the possibility of resonance in the array. Extensive prior testing <2> had provided good evidence that a counterpoise of this size would provide a fair approximation of the elusive "Perfect Ground", and should allow uniformity of testing without concern about anomalies in the ground system. Tests were conducted in the 27 to 30 MHz. range.

Graph I shows the shortening effect found for the physical length of an electrical 1/4 wavelength vertical monopole antenna over a counterpoise. As mentioned, this graph takes into account ALL factors that cause a vertical antenna to have a physical height less than an electrical 1/4 wavelength.

Further testing produced the base resistance figures shown in Table I. The lower than expected values for the "fatter" radiators were of concern until we noticed the work of Richmond <3> which indicates similar values for monopole antennas operating over a circular disk (i.e., a solid counterpoise).

II. CAPACITIVE BOTTOM LOADING OF VERTICAL ANTENNAS

After the tests referred to above had been completed and evaluated, a nagging question remained: Had some factor been missed that would help to explain the unexpectedly short heights found for 1/4 wavelength vertical monopoles?

Some months later the first clue to the unusually short antenna heights appeared when we built and tested a number of 440 MHz. folded monopole antennas over counterpoises.

An extensive series of tests of these antennas showed that:

1) The resonant frequency of a 1/4 wavelength vertical antenna used with a counterpoise varies as the size of the ground system (or plate, in the designs tested) under the counterpoise: the larger the ground system, the lower the resonant frequency; and

2) The resonant frequency of a vertical antenna used with a counterpoise varies as the distance between the counterpoise ground: the greater the distance, the higher the resonant frequency.

In other words, the capacity between the counterpoise and ground is acting to CAPACITIVELY BOTTOM LOAD THE VERTICAL RADIATOR.

An additional series of tests were next conducted to better define and quantify the capacitive bottom loading effect. In deriving the test program it was considered that this effect may be described as follows:

As the frequency of operation is raised, an antenna of fixed height looks at its base feed point like an increasing resistance in series with a decreasing capacitance. The resulting inductive reactance at the feed point must be tuned out, which necessitates the use of a capacitive reactance, which is provided by a capacitor.

In the antennas tested, capacity was added between the feed point of the antenna and the ground system, in order to supply the required capacitive reactance. By varying the value of this capacitive reactance the frequency at which the base impedance of the antenna is purely resistive, i.e., its resonant frequency, was varied.

A number of antennas for use on the 440, 145 and 29 MHz. amateur bands have been built to evaluate the practical aspects of Capacitive Bottom Loading. All have worked extremely well. For example, a 29 MHz. model was found to be "tunable" from 25.9 to 31.5 MHz without changing the height of the vertical radiator. With 100 watts input a small "trimmer" capacitor was found to be satisfactory to perform the Bottom Loading function. Performance on the "10 meter" amateur band has been excellent.

III. IMPEDANCE TRANSFORMATION PROVIDED BY FOLDED MONOPOLE ANTENNAS

The folded monopole antenna consists of two or more parallel, vertical, elements approximately 1/4 wavelength high. These elements are at right angles to, and fed against, a suitable counterpoise, ground plane or other artificial ground system. IEEE describes a folded monopole as being " A monopole antenna formed from half a folded dipole with the unfed element(s) directly connected to the imaging plane."

Folded monopole vertical antennas have the unique ability of presenting various values of base impedance, depending on the number of elements used, their relative diameters and the spacing between the elements. Excellent data is available <4> on the impedance transformation that may be accomplished with folded DIPOLE antennas, but not folded MONOPOLES.

Common practice has been to feed most vertical antennas with coaxial cable having a nominal impedance of 50 ohms. As the base impedance of the usual "1/4 wavelength" vertical antenna is only a fraction of 50 ohms, an impedance matching device is required to match the coax feed line to the antenna. System efficiency is improved if the antenna can be designed to present a 50 ohm impedance at its feed point.

It was for this reason that several thousand measurements were made to determine- for the first time- what impedance transformation can be accomplished by changing the relative diameters and spacing of the elements of a folded monopole antenna.

The element heights used were those determined by the test program that has just been described. Center test frequency was 29.0 MHz. As in the previous tests, an artificial ground system composed of a 64 radial counterpoise was utilized.

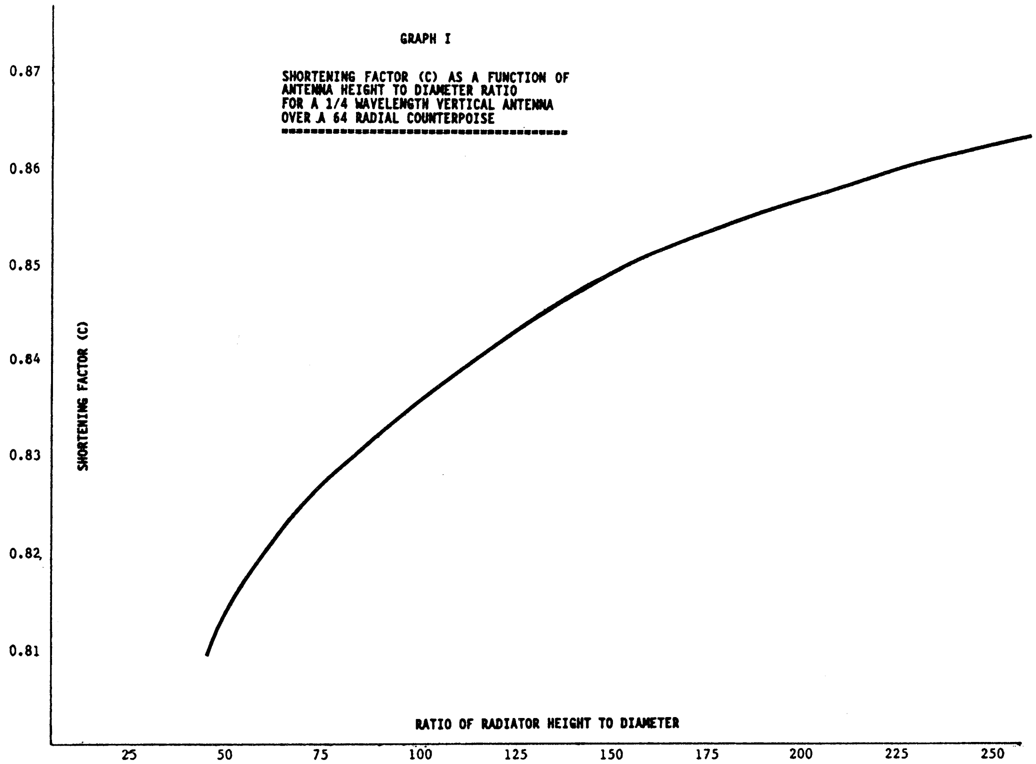


TABLE I

BASE RESISTANCE OF 1/4 WAVELENGTH VERTICAL ANTENNAS OVER A 64 RADIAL COUNTERPOISE

UNIPOLE DIAMETER	ACTUAL HEIGHT	H/D RATIO	BASE RESIS.	RESONANT FREQUENCY	THEORETICAL HEIGHT	C FACTOR
.125"	7.41'	712	33.5 Ohms	29.1 MHz.	8.45'	0.877
.375	7.45	238	29.0	28.45	8.65	0.861
.375	7.41	237	29.0	28.4	8.60	0.861
.375	7.38	236	29.0	28.7	8.57	0.861
.625	7.44	143	25.0	28.1	8.46	0.849
.625	7.38	142	25.0	28.2	8.72	0.846
.625	7.33	141	25.0	28.4	8.66	0.846
.625	7.17	138	25.0	28.95	8.50	0.844
.875	7.43	102	23.5	27.7	8.88	0.837
.875	7.38	101	23.5	27.9	8.82	0.837
1.0625	7.26	82	22.5	28.0	8.79	0.826
1.3125	7.39	67	22.0	27.4	8.98	0.822
1.875	7.25	46	21.0	27.6	8.91	0.814
2.00	7.25	44	21.0–	27.5	8.95	0.810

"Theoretical Height" is based on the formula : $H = \frac{246}{f(MHZ)}$

TABLE 2

IMPEDANCE TRANSFORMATION PROVIDED BY TWO ELEMENT FOLDED MONOPOLE ANTENNAS

MAIN ELEMENT DIAMETER	DROP WIRE DIAMETER	SPACING BETWEEN ELEMENTS	BASE RESISTANCE
1/8"	5/8"	4"	72 ohms
		7	75
	7/8	4	67
		7	72
	1 5/16	2	52
		10	73
	2	4	54
3/8	5/8	4	74
	7/8	4	73
	1 5/16	4	71
		7	73
	2	4	54
		10	72
5/8	2	4	71
		10	74
7/8	2	4	72
		7	74
		10	75

Table 2, above, shows selected conditions that were found to result in base impedance values close to those of the common 50 and 72 ohm coaxial cable.

:The last test series provides new data permitting one to design a folded monopole antenna having a specific base impedance. This data will permit the choice of element sizes and spacings to achieve a wide variety of impedances for matching, phasing, etc.

IV. SUMMARY

The test programs described above provide a considerable amount of new data on vertical antennas, with important practical implications:

:Through the use of Graph I proper dimensions may now be derived for 1/4 wavelength vertical monopole antennas over counterpoise, or equivalent,ground systems. This data has not been available in the past, as far as we can determine.

:The concept of Capacitive Bottom loading is explained. Practical applications of this convenient and efficient method of resonating vertical antennas have been constructed.

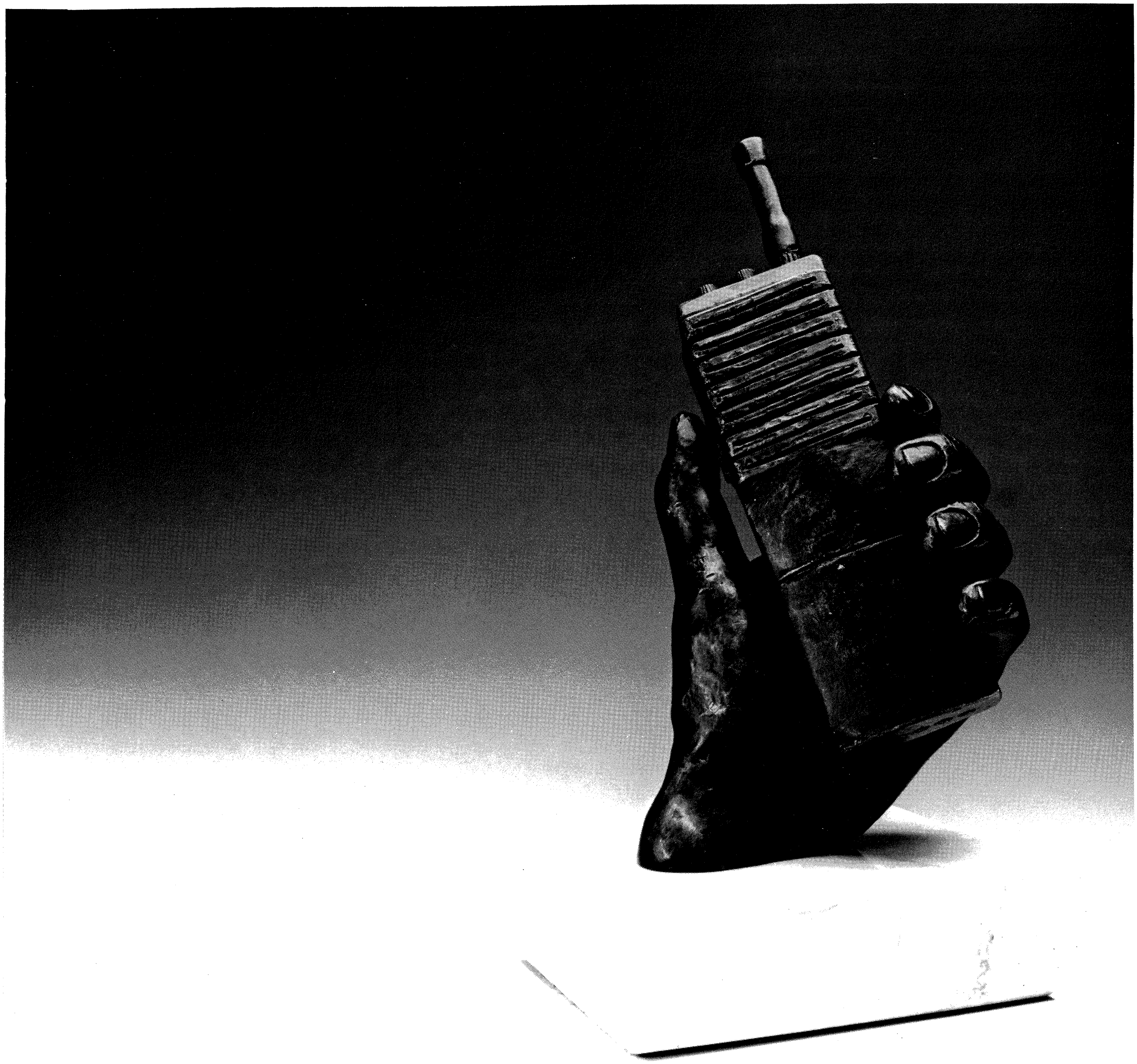
V. REFERENCES

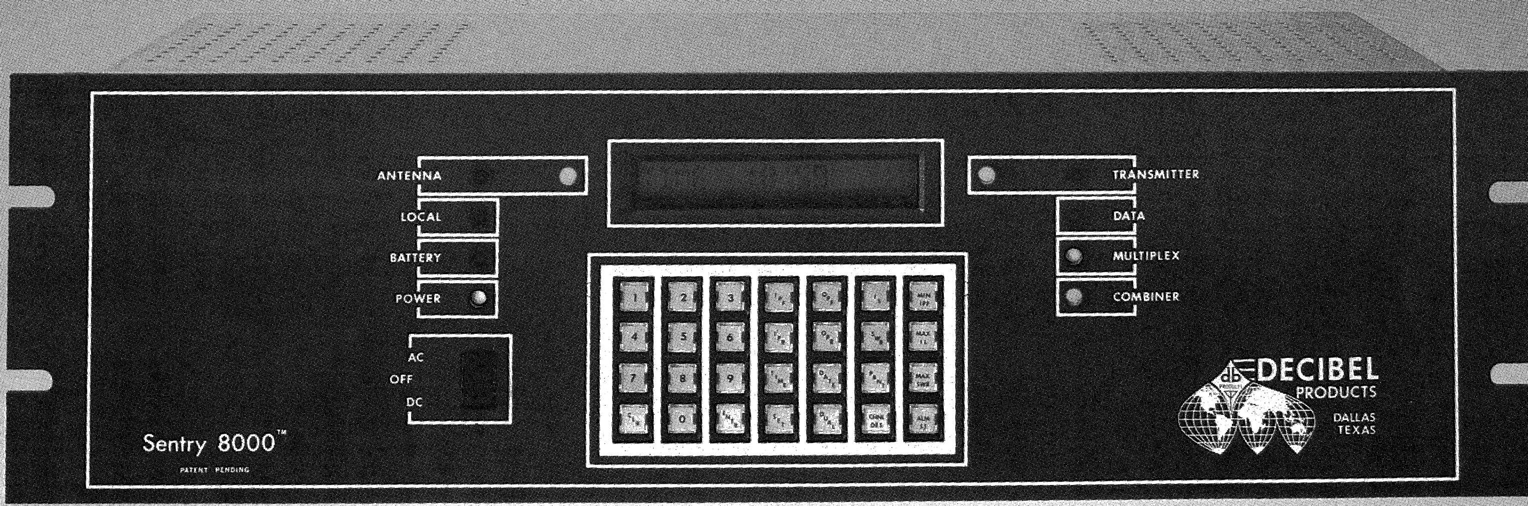
1. "IEEE Standard Dictionary of Electrical and Electronic Terms", IEEE, Third Edition, 1984

2. Doty, Frey and Mills, "Characteristics of the Counterpoise and Elevated Ground Screen", Professional Program, Session 9, Southcon (IEEE), January 1983.

3. J.H.Richmond, "Monopole Antenna on Circular Disk", IEEE Transactions on Antennas and Propagation, Vol. AP-32, No. 12, December 1984.

4. "The ARRL Antenna Book", American Radio Relay League, 15th Edition, 1988. Chapter 2, pp. 2-32, 2-33.





Install the Sentry 8000™ and you may never have an upset customer again!

You'll also profit from:
(1) More up-time!
(2) Less routine maintenance!
(3) Lower repair costs!

The Sentry 8000 is a microprocessor controlled, remote site monitor with RAM, EPROMs and CMOS circuitry. It receives information from special sensors placed on your equipment and reports the condition of transmitters, combiners, antennas, transmission lines and selected environmental characteristics.

Alert and Alarms

Green status LEDs mean that your equipment is operating within preset limits. Red LEDs indicate problems and alarms can be sounded.

A 16-character LCD display presents answers from inquiries entered via the 28-button keyboard.

All data can be communicated via an RS-232 interface and a built-in modem — 300 or 1200 baud — to a terminal, printer or computer.

Relays can be controlled and parameters entered remotely.

Up to two variables may be displayed at one time, a valuable tool for retuning combiners.

Now ready for any 30-1000MHz system!

A single Sentry 8000 can monitor up to four antenna systems with up to 18 transmitters or two antenna systems with up to 20 transmitters. It can be used on any 30-1000MHz communication system, including trunked, conventional, paging, cellular, IMTS, mobile radio dispatch and aviation. Decibel now has standard software to accommodate almost any transmitter site.

A Sentry 8000 is currently monitoring a 20-channel system on one antenna!

For more information write Marketing, Decibel Products, Inc., P.O. Box 569610, Dallas, TX 75356-9610. Telephone: (214) 631-0310. Telex: 73:0212. FAX: (214) 631-4706.

Order the Sentry 8000. It has the features and the technology to solve your problems.

If you want quality, you want Decibel! Leadership since 1947.

Factory Authorized Warehouses: Tekcom, Inc., Costa Mesa and Union City CA; **Talley Electronics Co.**, Hayward CA, Santa Fe Springs CA and Phoenix AZ; **CW Electronics**, Denver CO; **The Antenna Farm**, Overland Park KS; **M. Hutton Co.**, Dallas TX; **ComMar, Inc.**, Westport, MA; **Tessco, Inc.**, Hunt Valley MD, Tampa FL, Schaumburg IL, and Sparks NV; **Primus Electronics Corp.**, Joliet IL.
International: Marketronics, Sunrise FL (for South America), **Lenbrook Industries, Ltd.**, (Canada) St. Leonards, Quebec; Calgary, Alberta, and Pickering, Ontario, **RAC**, (Italy) Milan; **Walmore Electronics, Ltd.**, (England) London; **OmniTronics Enterprises PTE Ltd.**, (Singapore), **Sistemas Profesionales S.A.**, (Mexico), Mexico City; **R.F. Devices Pty.**, (NSW Australia) Miller.

Also consider Decibel's advanced Fire Power™ filter products, Aeroglas™ base station antennas, and mobile antennas.

The Midland Syn-Tech™ Challenge made believers out of some pretty tough customers!

"Superior reliability"

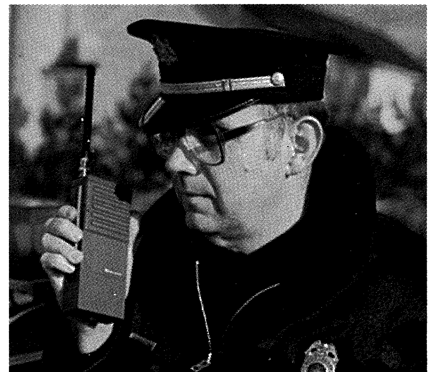
"Radios in our off-road land survey vehicles really take a beating. But the reliability of our Syn-Tech's has proven far superior to anything else I've experienced in 12 years as a two-way user."

Charles Sterling, President
Sterling Engineering, Inc.
Maryville, TN

"Operational flexibility"

"The large channel capacity, plus the ability to reprogram the Syn-Tech quickly, means I can operate anywhere in or out of my service territory on an instant's notice."

Harold M. Knabe
Public Information Officer
Kansas City, MO Fire Department



"One radio that does it all"

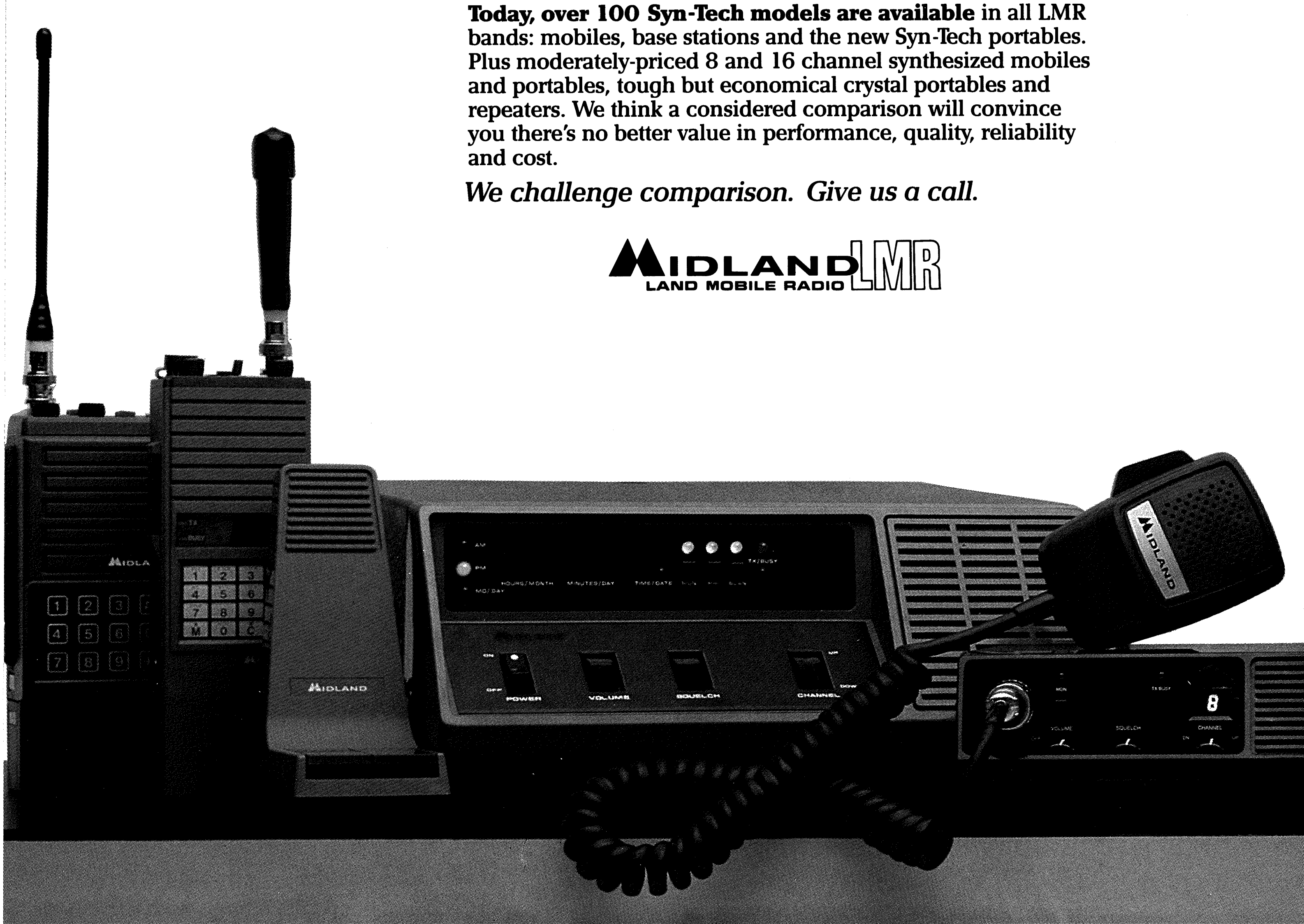
"Working in an area that has about 15 frequencies, the Midland LMR has solved our communications problems."

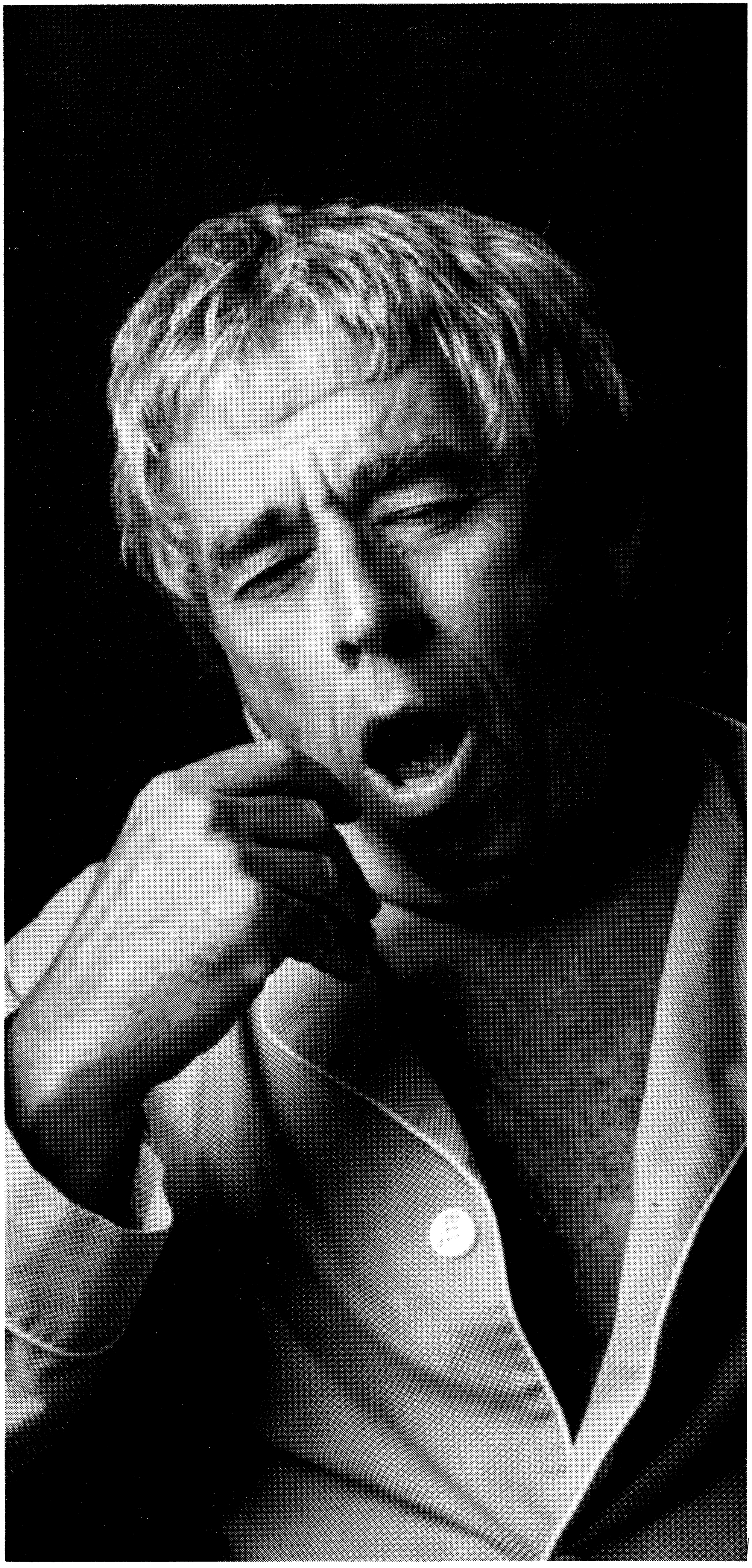
Ronald H. Quinter, Chief
Womelsdorf Borough Police
Womelsdorf, PA

Today, over 100 Syn-Tech models are available in all LMR bands: mobiles, base stations and the new Syn-Tech portables. Plus moderately-priced 8 and 16 channel synthesized mobiles and portables, tough but economical crystal portables and repeaters. We think a considered comparison will convince you there's no better value in performance, quality, reliability and cost.

We challenge comparison. Give us a call.

MIDLAND LMR
LAND MOBILE RADIO





E.F. Johnson believes it's time to change some attitudes about the 2-way radio market.

For too many people, the two-way radio market is one big yawn.

GE and Motorola. Motorola and GE.

But what they overlook is that for over 63 years, there's been an alternative. A better alternative. A radio company that offers more reliable products backed by the most experienced national dealer service organization in the business. And a longer history of radio innovation and refinement than either.

That company, as you've guessed, is E. F. Johnson.

Since 1923, we've been pacing the industry with the latest in product developments. Our trunking system is recognized as the standard in the industry. And the rest of our radios aren't far behind.

You'll find we have the largest nationwide network of locally owned dealers and factory-trained technicians, providing service, inventory and expertise right in your area.

You'll find a company that's large enough to handle the biggest jobs in the field, yet flexible enough to be responsive to smaller, customized projects.

We're not into washers, dryers, refrigerators or stereos. So our name isn't always on the tip of your tongue. But when it comes to two-way radio, we're beginning to look less and less like a challenger, and more and more like the leader.

To learn more, or to arrange for a custom demonstration of E. F. Johnson equipment, look in the Yellow Pages for the dealer nearest you, or call 1-800-247-8343.

JOHNSON®