The Effect of Supporting Structures on Simple Wire Antennas

Your tower does more than just support your antennas. You may be surprised at the results!

By John S. Belrose,* VE2CV

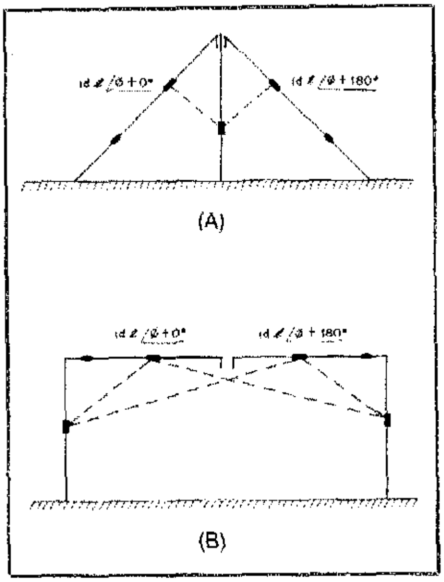

Fig. 1 — Drawings illustrating how antenna-current elements (idℓ) induce currents on conducting support tower(s). An inverted V (A) and a horizontal dipole (B) are shown.

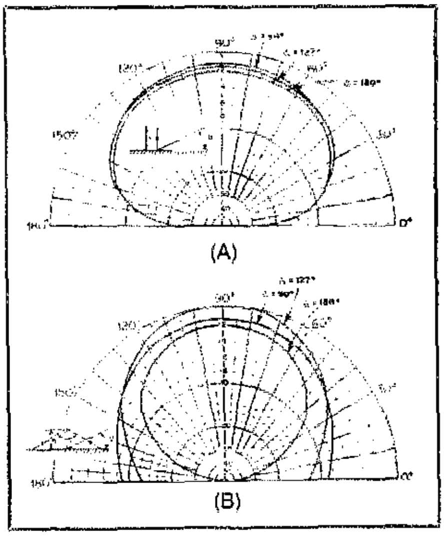

Fig. 2 — Vertical-plane, polar diagrams of an inverted-V antenna for two orthogonal planes and polarizations. A is for horizontal polarization in the plane broadside to the antenna, and B is for vertical polarization in the plane of the antenna.

Wire antennas, such as dipoles, inverted Vs and Delta Loops, are the most commonly used antennas for Amateur Radio communications on the lower hf bands (160, 80, and 40 m). Theoretical vertical-plane patterns for dipoles and inverted Vs at various heights above ground have been well documented.[1,2] Mayhead[3] has measured the vertical-plane patterns of dipoles, quads and Delta Loops on an improvised antenna pattern range. While his results are not in perfect accord with my measurements performed on a commercial antenna test range, the patterns he provided gave me the stimulus to begin my study.

Amateur wire antennas are typically supported by grounded metal towers between 50 and 60 feet high.[4] The supporting towers are therefore about the right height to be resonant (h~λ/4) at 80 m, and could affect the antenna radiation pattern markedly. Yet this fact has been ignored by the radio amateur; he usually takes no account of the fact that dipoles and Delta Loops radiate vertically polarized fields off their ends. The amateur normally is concerned only with the field that lies broadside to the antenna. Since this field is horizontally polarized and the towers are vertical, this may be the reason the influence of metal towers has been overlooked.

This article describes experimental measurements and theoretical model calculations for various wire antennas over a perfectly conducting ground plane, with and without the influence of metal support towers. The experimental testing was done at 200 MHz, employing a ground-level antenna-pattern range that has been described in *QST*.[5] Reradiation effects from the supporting towers are at a maximum, since the towers were approximately λ/4 high at the model frequency. A summary of the results given here has been published previously.[6]

The 1/2-λ Inverted V

The 1/2-λ inverted V is a resonant dipole with drooping ends. It is a very practical antenna, requiring only one support. Provided that the feed is balanced, the effect of a metal supporting tower on the radiation pattern is minimal. This can be seen in Fig. 1A. The current elements (idℓ) on each arm of the dipole will be in opposite phase, so currents that each induces on the tower will cancel. The vertically polarized pattern of the antenna is very sensitive to any imbalance, and a balun should be employed to provide balanced feed if a true bidirectional pattern is desired.

Vertical-plane patterns for various configurations of 1/2-λ inverted-V dipoles are shown in Fig. 2. The azimuthal patterns (not shown) are typical figure eights with maxima in the respective orthogonal directions for each polarization. When the included angle Δ between the two arms of a dipole is equal to 180°, this is the configuration of a horizontal dipole. For this pattern measurement, the antenna was supported by nonconducting towers.

The height (h) in Fig. 2, and others to

[1]Notes appear on page 35.

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follow, is $\lambda/4$. While no attempt was made to measure absolute gain, all patterns were taken at a constant power level employing a 50-Ω signal generator. With reference to the 1/2-λ dipole (Fig. 3), 0 dB corresponds to an overhead power gain ($\theta = 90°$) of 6 dBd. The gain differences measured for $\Delta = 127°$ and 90° are opposite to those that would be expected; this is because an inverted V with $\Delta = 90°$ is a better match to the 50-Ω feeder cable. The input impedance of a horizontal dipole is approximately 72 Ω.

For radio amateurs, the configuration $\Delta = 90°$ is optimum. This antenna provides high-angle radiation for short- to medium-distance communications, but the polarization is dependent on the azimuth; low-angle vertical polarization, for communication to distant stations, is maximum in the plane containing the antenna.

The 1/2-λ Dipole

The vertical plane radiation patterns for the 1/2-λ dipole are shown in Fig. 3. These are tracings of the observed patterns, with no smoothing. The "wiggles" on the curves are a range imperfection. Note that the conducting towers have little effect on the horizontally polarized field in the plane broadside to the dipole (Fig. 3A); the conducting towers have a significant effect on the low-angle ($\theta < 20°$) vertically polarized field in the plane of the dipole (Fig. 3B). In fact, the tower effect results in a significant field directed toward the horizon. The azimuthal patterns, not shown, were again typical figure eights, orthogonally directed for each polarization.

A qualitative explanation for these differences can be inferred from the sketch in Fig. 1B. The current elements ($id\ell$), which are located the same distance each side of the feed point, are of equal but opposite phase. Each element will induce a current on each supporting tower, and the resulting currents on the towers will not cancel. Therefore, a marked effect would be expected — particularly in the plane of the antenna and in the direction of the horizon, since this is the direction of maximum field strength from a vertical radiator.

The 1-λ, Apex-Down, Apex-Feed Delta Loop

A 1-λ, apex-down, apex-feed Delta Loop radiates essentially like a horizontal 1/2-λ dipole, and the resulting patterns, with and without *metal supporting* towers, should be similar to those found in Fig. 3. This expectation was confirmed by measurement (Fig. 4).

The measured patterns for the apex-down, apex-feed Delta Loop are replotted in Figs. 5 and 6 on a rectilinear format, and for comparison with theoretical calculations. A geometrical representation is shown in Fig. 7A. The theoretical gains (in dBi) G_ϕ and G_θ are the horizontally

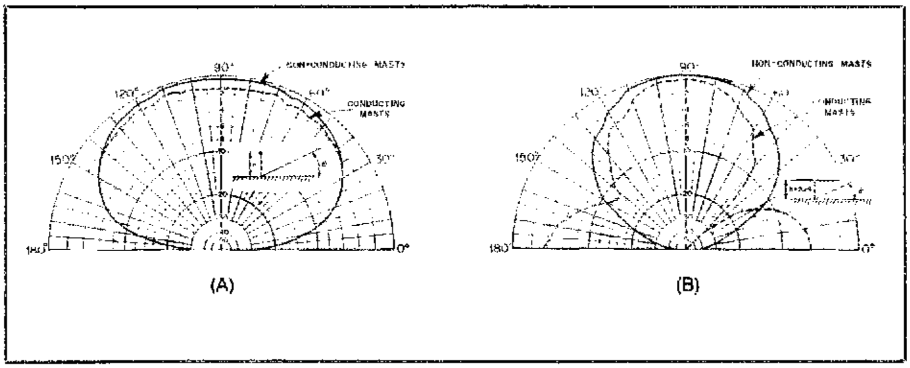

Fig. 3 — Vertical-plane polar diagram of a horizontal dipole antenna for two orthogonal planes and polarizations. A is for horizontal polarization in the plane broadside to the antenna, and B is for vertical polarization in the plane of the antenna. The continuous and broken curves are for nonconducting and conducting support towers, respectively.

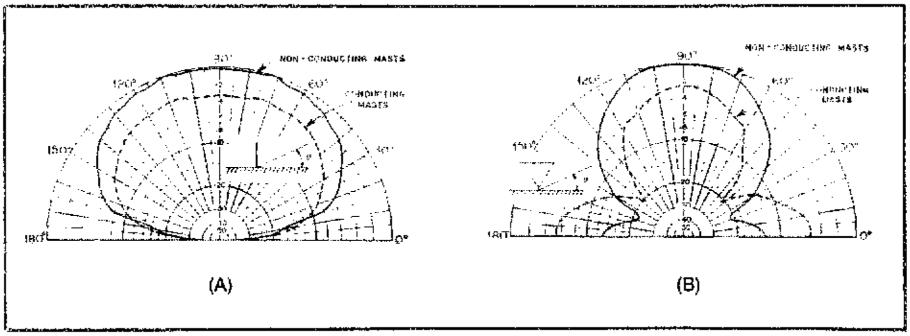

Fig. 4 — Vertical-plane polar diagrams of a 1-λ, apex-down, apex-feed Delta Loop for two orthogonal planes and polarizations. A is for horizontal polarization in the plane broadside to the antenna, and B is for vertical polarization in the plane of the antenna.

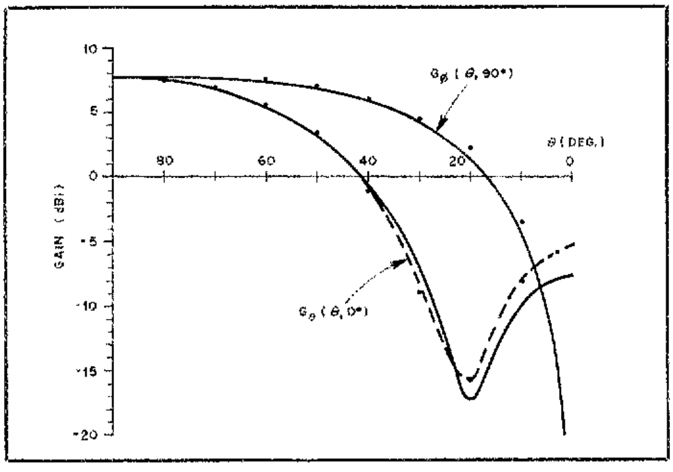

Fig. 5 — Calculated gain curves for the apex-down, Delta-Loop antenna shown in Fig. 7A, where the support towers are nonconducting. The dots and broken line represent measured values.

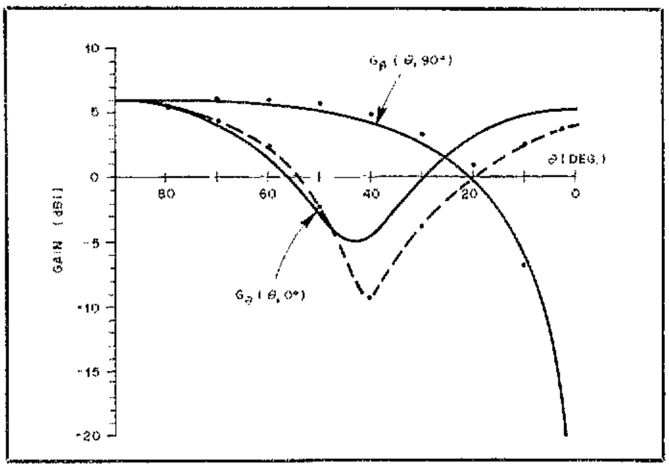

Fig. 6 — Calculated gain curves for the apex-down, Delta-Loop antenna shown in Fig. 7A, where the support towers are conducting. The dots and broken line represent measured values.

and vertically polarized power gains, respectively. The theoretical results (shown by the solid lines) were calculated by a modern numerical electromagnetic code (NEC) developed by Burke and others.[7] The broken lines have been plotted from data obtained through measurement. While an exact agreement between prediction and measurement does not exist, it is clear that the effect of the conducting tower is well predicted by the NEC. While no attempt was made to ensure that the numerically modeled 1-λ Delta Loop was exactly resonant, it is interesting to note that a marked change in input impedance was predicted when metal towers are employed. With nonconducting towers, the input impedance of a 1-λ loop (in free space) was calculated to be $157\ \Omega\ \underline{/-35^\circ}$, which changed to $293\ \Omega\ \underline{/-49^\circ}$ when conducting towers were modeled.

The 1-λ, Apex Down, Top-Corner-Feed Delta Loop

Figs. 8 and 9 are patterns for the 1-λ, apex-down, top-corner-feed Delta Loop. With nonconducting towers, the radiation is predominantly vertically polarized (see Fig. 8), with maximum field strength in the plane broadside to the antenna (Fig. 9). Gain in this broadside direction is about 1 dBd. With conducting towers, the bidirectional nature of the vertical polarization pattern (in the plane of the antenna) is modified (Fig. 8B). The ellipsoidal azimuth pattern is distorted into a weak cordiodal pattern (Fig. 9), with a slight field-strength maximum in the direction of the feed point.

The 1-λ, Apex Up, Lower Corner-Feed Delta Loop

This antenna is a practical one, since only a single supporting tower is needed. The arrangement is shown in Fig. 7B. Theoretically derived gain patterns are shown in Figs. 10 and 11. While a conducting tower noticeably modifies the pattern, the effect is minimal and, from a practical standpoint, can be ignored. The gain pattern in Fig. 11 (where a conducting tower is present) shows that the radiation is predominantly vertically polarized, with maximum field strength toward the

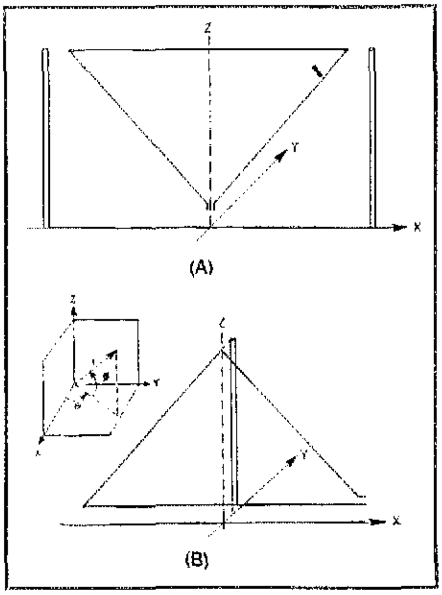

Fig. 7 — Geometry for (A) an apex-down, Delta-Loop antenna and (B) an apex-up, Delta-Loop antenna. Insert provides text coordinate reference.

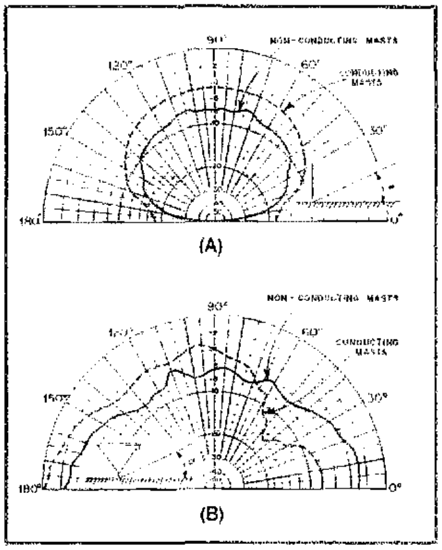

Fig. 8 — Vertical-plane, polar diagrams for a 1-λ, apex-down, top-corner-feed Delta Loop for two orthogonal planes and polarizations, measured (A) for horizontal polarization in the plane broadside to the antenna and (B) for vertical polarization in the plane of the antenna.

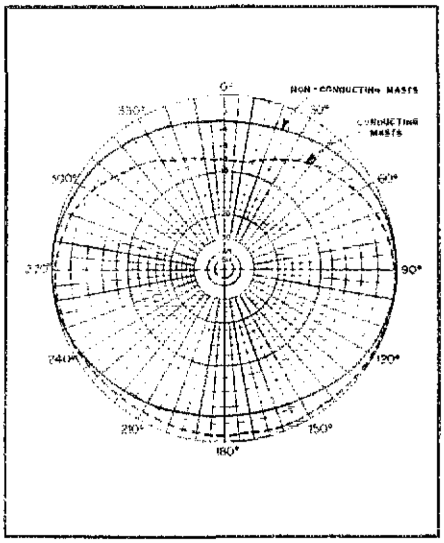

Fig. 9 — Azimuth polar diagram for vertically polarized radiation of a 1-λ, apex-down, top-corner-feed Delta Loop, measured at an elevation angle $\theta = 10^\circ$. The antenna was in the 0° - 180° plane, with the feed point on the 0° side.

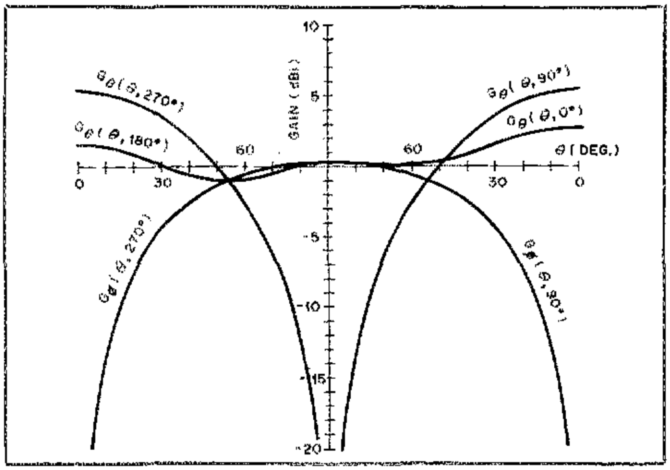

Fig. 10 — Calculated gain curves for the apex-up, Delta-Loop antenna shown in Fig. 7B, where the support tower is nonconducting.

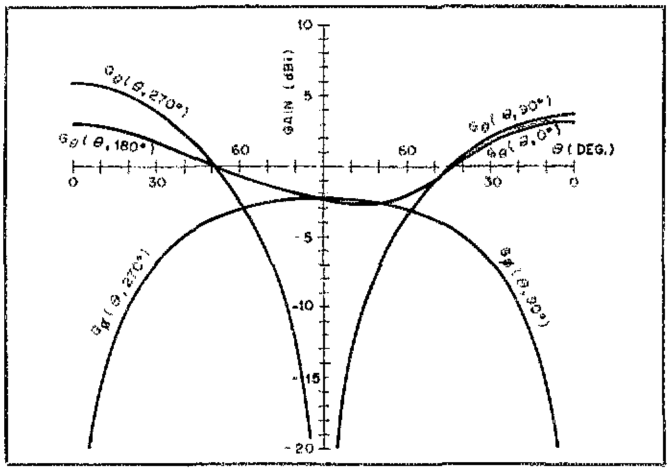

Fig. 11 — Calculated gain curves for the apex-up, Delta-Loop antenna shown in Fig. 7B, where the support tower is conducting.

horizon. Gain is greater than 3 dBi at all azimuths. It should be noted that the gain of a 1/4-λ monopole over a perfectly conducting earth is 5.16 dBi (3 dBd); therefore, the 1-λ Delta Loop has not provided increased "gain." However, it provides a means to obtain, with a single supporting tower, an efficient antenna without the need for a radial ground system. Like all 1-λ loops, it also can be used on its harmonic frequencies. Dipoles and monopoles are resonant on odd harmonic frequencies, whereas the 1-λ loop is resonant on all its harmonic frequencies.

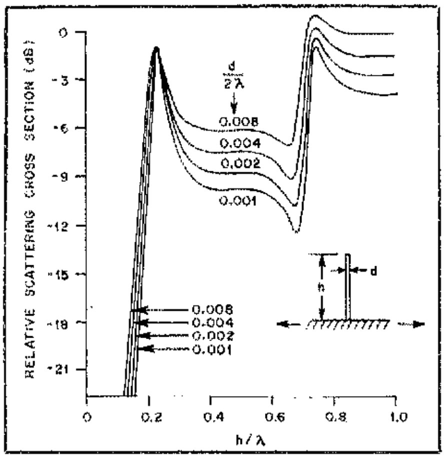

Fig. 12 — Normalized scattering cross section (along the ground plane) for a grounded, conducting tower. The scattering cross section is a quantitative measure of the reradiated signal power density, with respect to the plane wave incident on the scatterer.

Effect of Varying Tower Height

A grounded, conducting tower reradiates strongly when it is either 1/4- or 3/4 long, and less when it is of any other height. Fig. 12 illustrates how the relative scattering effect for grounded metal towers of various thickness varies with tower height.[8] While this parameter cannot be used to simply predict the radiation patterns for wire antennas suspended on towers of different heights, it does provide some insight into the magnitude of the effect. For example: If towers that were approximately λ/4 long at 80 m were used to support a 160-m antenna (h ~ λ/8), the magnitude of the reradiated fields on 160 m would be 22 dB less than on 80 m; at 40 m (h ~ λ/2), the effects would be 5-9 dB less (dependent on the thickness of the tower).

Acknowledgments

The author wishes to express his thanks to L. R. Bode, who built the model antennas, and to Max Royer, of the Communications Research Center, who carried out the numerical modeling. Thanks also to J. G. Dunn, of the National Research Council, who measured the antenna patterns on their test range.

Notes

[1] *The ARRL Antenna Book*, 13th ed. (Newington: ARRL, 1974), pp. 55-56.

[2] D. Covington, "Radiation Patterns of Dipoles Over Perfect Ground, *QST*, April 1970, pp. 46-50.

[3] L. Mayhead, "Loop Aerials Close to Ground," *Radio Communication*, May 1974, pp. 298-301.

[4] m = feet × 0.3048.

[5] J. Belrose, "The Half Sloper — Successful Deployment is an Enigma," *QST*, May 1980, pp. 31-33.

[6] J. Belrose, "The Effects of Metal Supporting Towers on the Radiation Pattern of Simple Wire Antennas," *1981 IEEE Second International Conference on Antennas and Propagation*, Conf. Proc. No. 195, Vol. 1, April 1981, pp. 84-87.

[7] J. Burke, A. Poggion, J. Logan and J. W. Rockway, "NEC — Numerical Electromagnetic Code for Antennas and Scattering," *1979 IEEE International Symposium on Antennas and Propagation*, Seattle, WA, Vol. 1, June 1979, pp. 147-150.

[8] G. Royer, "The Effects of Re-radiation from High-rise Buildings and Towers Upon the Antenna Patterns for AM Broadcast Arrays," *1981 IEEE International Symposium on EMC*, Boulder, CO, August 1981.

New Books

☐ *The Complete Handbook of Amplifiers, Oscillators, and Multivibrators*, by Joseph J. Carr. Published by Tab Books, Inc., Blue Ridge Summit, PA 17214. Softcover, 364 pages, Tab book no. 1230. First edition 1981, 5-1/2 × 8 inches, $8.95.

From the opening pages of this book dealing with basic semiconductor theory, until the closing chapter on microwave devices, the ham and nonham alike will find a wealth of information dealing with electronic fundamentals and basic solid-state devices, along with devices such as oscillators and multivibrators.

Filling the book with practical working examples, author Carr has managed to cover quite a broad area of electronics in a comprehensive manner. In fact, he discusses some topics in this book that are not treated in very many other books. For example, entire chapters are devoted to designing FET circuits, utilizing isolation amplifiers, tackling operational amplifier problems, explaining the CDA (current difference amplifier) and OTA (operational transconductance amplifier), voltage-to-current converters, choppers, carrier and lock-in amplifiers. The chapter on microwave devices (Gunn devices, IMPATT devices and TRAPATT diodes) is especially valuable for the above 1-GHz experimenter.

Math is used where needed but is not overdone. The only problem with the book is an occasional erroneous reference in the text, mostly to figure and graph numbers, but this problem is not overtaxing. All in all, the book serves as interesting reading for any ham as well as a useful addition to the reference shelf. — *Al Gordon, WD6HAK*

☐ *Practical RF Design Manual*, by Doug DeMaw. Published by Prentice-Hall, Inc., Englewood Cliffs, NJ 07632. First edition, 1982. Hard-bound, 6 × 9 inches, 246 pp., including index, $24.95.

The title of this textbook says it all! It is a practical, down-to-earth manual for those of us in the ham fraternity who like to "roll their own." Even if you are not interested in building your own equipment, the vast amount of information presented in this book will give you a better understanding of how and why circuits behave as they do. The text is very readable, so even if your electronic knowledge is not "extra class," you should be able to gain a wealth of information. The professional electronics engineer should also find this book valuable.

Chapter 1 leads you through transmitter and receiver fundamentals, delving into frequency stability, spectral purity, SWR protection circuits, etc. The section on receiver dynamic range and how to measure it is very worthwhile. If your understanding of this much-talked-about subject is fuzzy, it may be worth the price of the book for this information alone. Sensitivity, selectivity and noise limiting are also covered.

Chapter 2 is all about frequency control. Crystal oscillators, L-C rf oscillators and heterodyne frequency generators are covered, and many practical circuits are given.

Chapters 3 and 4 deal with small and large rf amplifiers, including design criteria and many explanatory circuits. Particular emphasis is placed on amplifier stability, biasing, broadbanding techniques. In addition, there is a lot of material on VMOS power FETs.

The final chapters will fill you in on frequency multipliers, mixers, balanced modulators, detectors, i-f amplifiers, filters and agc systems.

One worthwhile and handy feature of this book is that the formulas, and results, are entered on the diagram so you do not have to go searching through the text for them. I found some errors in the diagrams that I can only assume crept in when the draftsperson copied the originals to the Prentice-Hall format. The proofreaders also missed them!

I have been building ham gear for over 30 years, and I found many new and useful ideas in the pages of this book that may be applied to almost any project. It is a worthwhile addition to any technical library. — *Norm Bradshaw, W8EEF*