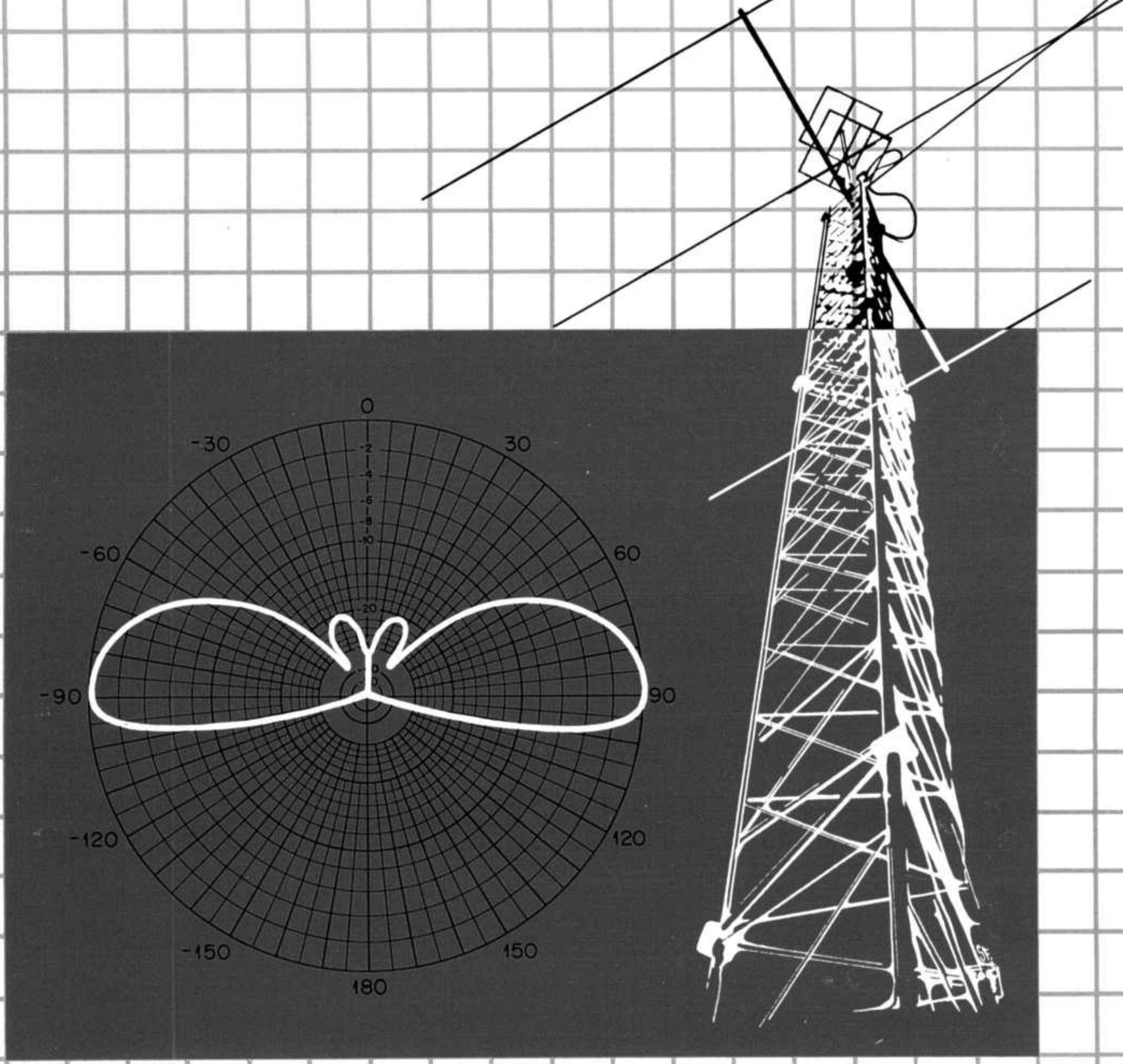
QEX 55

$1.75

SEPTEMBER 1986

The ARRL Experimenter's Exchange



QEX (ISSN: 0886-8093) is published monthly by the American Radio Relay League, Newington, CT USA.

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Subscription rate for 12 issues:
In the US by Third Class Mail:
ARRL Member $6, nonmember $12;
US by First Class Mail:
ARRL Member $11, nonmember $17;
Elsewhere by Airmail:
ARRL Member $21, nonmember $27.

QEX subscription orders, changes of address, and reports of missing or damaged copies may be marked: *QEX* Circulation.

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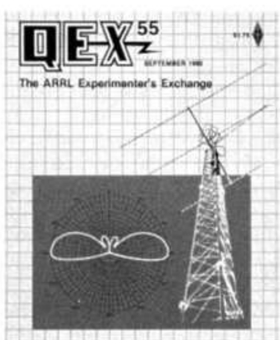
TABLE OF CONTENTS

COLUMNS



ABOUT THE COVER

An antenna is the most important part of an Amateur Radio station. Without one, effective communications cannot take place. Each antenna has its own radiation pattern. A pattern plot informs the user where the signal is being directed. Does your pattern resemble that which appears on our cover?

THE AMERICAN RADIO RELAY LEAGUE, INC

The American Radio Relay League, Inc. is a noncommercial association of radio amateurs, organized for the promotion of interest in Amateur Radio communication and experimentation, for the establishment of networks to provide communications in the event of disasters or other emergencies, for the advancement of the radio art and of the public welfare, for the representation of the radio amateur in legislative matters, and for the maintenance of fraternalism and a high standard of conduct.

ARRL is an incorporated association without capital stock chartered under the laws of the State of Connecticut, and is an exempt organization under Section 501(c)(3) of the Internal Revenue Code of 1954. Its affairs are governed by a Board of Directors, whose voting members are elected every two years by the general membership. The officers are elected or appointed by the Directors. The League is noncommercial, and no one who could gain financially from the shaping of its affairs is eligible for membership on its Board.

"Of, by, and for the radio amateur," ARRL numbers within its ranks the vast majority of active amateurs in the nation and has a proud history of achievement as the standard-bearer in amateur affairs. As its membership journal, ARRL publishes *QST* monthly.

A bona fide interest in Amateur Radio is the only essential qualification of membership; an Amateur Radio license is not a prerequisite, although full voting membership is granted only to licensed amateurs in the US and Canada.

Purposes of *QEX*:

1) provide a medium for the exchange of ideas and information between Amateur Radio experimenters
2) document advanced technical work in the Amateur Radio Field
3) support efforts to advance the state of the Amateur Radio art.

All correspondence concerning *QEX* should be addressed to the American Radio Relay League, 225 Main Street, Newington, CT USA 06111. Envelopes containing manuscripts and correspondence for publication in *QEX* should be marked: Editor, *QEX*.

Both theoretical and practical technical articles are welcomed. Manuscripts should be typed and double spaced. Please use the standard ARRL abbreviations found in the 1985 and 1986 ARRL Handbooks and in the January 1984 issue of *QST*. Photos should be glossy, black-and-white positive prints of good definition and contrast, and should be the same size or larger than the size that is to appear in *QEX*.

Any opinions expressed in *QEX* are those of the authors, not necessarily those of the editor or the League. While we attempt to ensure that all articles are technically valid, authors are expected to defend their own material. Products mentioned in the text are included for your information; no endorsement is implied. The information is believed to be correct, but readers are cautioned to verify availability of the product before sending money to the vendor.

Empirically Speaking. . .

Packet Radio—We're Five Years Down the Road

In just five years, amateur packet radio has grown from virtually nothing to about 18,000 units worldwide. Packet radio's rich history is well documented in the *1986 ARRL Handbook,* and there are numerous people and organizations to recognize for that. Every now and then, however, it is good to stop to drink in the protocols and smell the packets.

No one has an accurate count, but we now have hundreds of digipeaters across America. There are not very many gaps in a chain that would permit relay of packets from coast to coast. Those who send the first packet will qualify for the Pacific Packet Radio Society's "Golden Packet" award. Even when this is achieved, the transcontinental transit time will be dreadfully long, certainly not fast enough for real-time QSOs. But then, we'll have plenty to do over the years ahead to replace the inaugural VHF simplex 1200-bit/s relay system with a UHF full-duplex system running at least 56 kbit/s.

Also in place is a group of about 35 active HF packet-radio stations that function as HF/VHF gateways for their areas. Messages sent on VHF into a packet bulletin board system (PBBS) running WØRLI software are translated to HF, sent across country, then stored in a PBBS there for either forwarding to another or for access on VHF by the ultimate addressee station. Transit time for messages can run from minutes to days with the present setup. On July 16, the ARRL Ad Hoc Committee on Amateur Radio Digital Communication mailed questionnaires to 43 HF packet stations now active, recently active or having expressed interest in operating an HF/VHF gateway station. In the package mailed to these stations was a conceptual model for further development of an HF packet-radio relay network for the United States. Twenty questionnaires have been received as this is written. The packet-radio community will be advised of the results of the survey and the revised HF development model when completed. For those not directly involved, the immediate goal is to have an HF packet-radio relay network capable of moving messages between any two HF/VHF gateway stations any time of day or night, in minutes, not hours. Involved in this development will be a request to the FCC for Special Temporary Authority for some stations to operate automatically and unattended.

PBBSs are also used for message transfers at VHF. Much of it is informal traffic between packeteers, but some are formal National Traffic System (NTS) messages. The NTS (voice/CW) and PBBS formats aren't 100% compatible at this point of development, and the ARRL Board has urged improvement in this area (see Minute 33 of the Board Meeting in September *QST*). The ARRL Blue Ribbon Committee and Digital Committee will be working together to ensure easy refile between the voice/CW nets and packet nets.

Some early effort has gone into meteor scatter and satellites to leapfrog over VHF terrestrial digipeater chains, but much more remains to be done. AMSAT-OSCAR 10's problems have prevented it from becoming the panacea for long-haul packet radio. But we should have more success with JAS-1 and AO Phase 3C. Even earth-moon-earth (EME) offers another mode of packet propagation if W3IWI/KL7 has his way.

So far, I have talked a lot about the "pipeline" that will carry packets. To some packeteers, the fun is in building the pipeline; they'll go off and play some other game when it's built. They take for granted that packet is good for something otherwise they wouldn't have worked so hard laying pipe.

To many more, however, the fun is in the application. Bulletin boards seem to have the spotlight now. They are a great convenience for sending and receiving messages between packeteers, and are repositories of interesting mail. Some amateurs have used packet radio for status boards, such as to keep track of people (and horses) in various 'athons or emergency situations. Yet, we haven't even scratched the surface of possible amateur packet-radio applications.

Transmission of freeze-frame images (a la SSTV and FAX) is possible at today's packet data rates if someone comes up with conversion software. With increasingly cheaper RAM and disk mass storage, creation of "image banks" should not be very far in the future. Virtually full-motion television will be feasible in the future once we have a network that operates at speeds of at least 56 kbit/s. At such speeds, it should be possible to multiplex data and digitized speech.

One often hears that we're limited only by our imagination. Unfortunately, it takes a finite amount of time to do things. One also hears bystanders criticizing the doers for not doing more faster.—W4RI

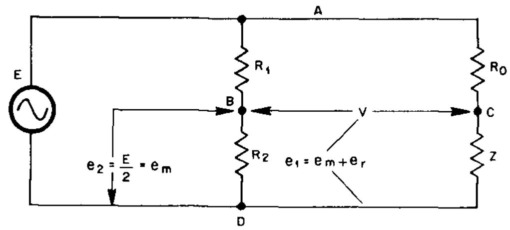
Correspondence

Book Source Needed

In the April 1986 Correspondence column, Mr Cooper's letter made reference to the book, *EMP Radiation and Protective Techniques* by Ricketts, Bridges and Miletta. I have searched for this book, but have found that it is out of print. Does anyone know where a copy can be purchased?—*Nick Leggett, N3NL, 1500 Massachusetts Ave, NW, Apt 610, Washington, DC 20005*

A Graphical Method of Measuring Impedances

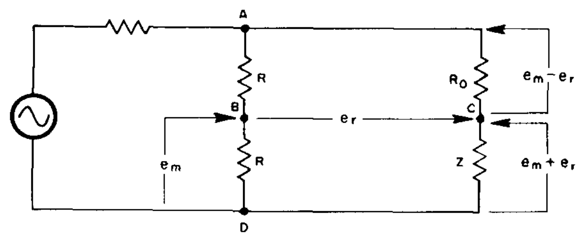
Refer to Ken Simon's, W3UB, paper in the May 1986 issue of *QEX*. Let us examine voltages in a bridge: W3UB indicates in Fig 4:



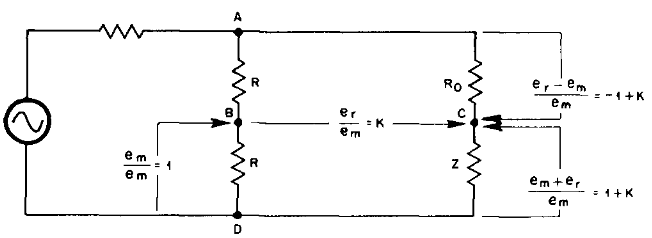
where

e_m is the incident voltage wave
e_r is the reflected voltage wave
e_r/e_m = k is the voltage reflection coefficient
$Z = R_0 (1 + k/1 - k)$

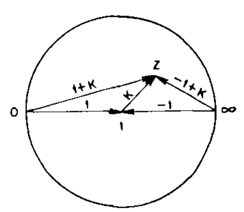
This is a vector equation and it can be solved using a graphical method. First, the circuit may be modified and completed:



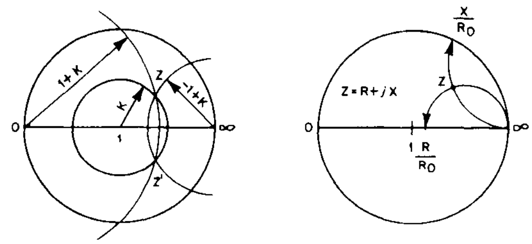
Dividing all terms by e_m gives:



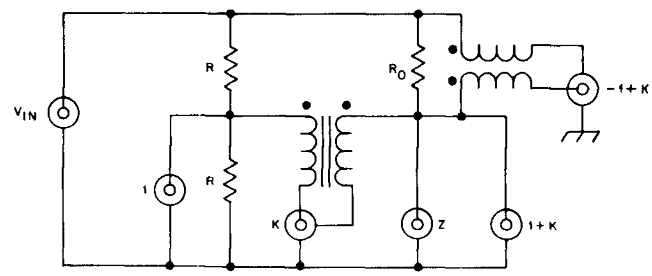
Then, looking at the Smith Chart, we see that:



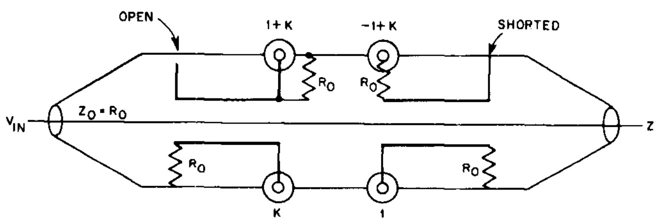
Knowing the module of k, 1 + k and 1 − k, we can draw this figure on a Smith Chart and read active and reactive components of Z.



(Chose between Z and Z′. It is simple with a suitable fixed capacitor connected in series or parallel with Z.)
How would you measure these different voltages?
With a bridge:



With a directional coupler:



—*Philippe Petit, 25 Rue Des Templiers, F51100 Reims, FRANCE*

Bits

Cleaning Tips

Chemtronics has been a leading producer of high purity cleaning agents since 1958. It is no surprise that Foamtips™ and Cottontips™ is just what the janitor ordered to clean sensitive surfaces. Many of these areas are hard to get at and the long-handled swab is proven to be a convenient tool. The lint free, urethane foam (or cotton) swab gently, but effectively, cleans magnetic heads and discs, computer components and electronics assemblies. These are only several of the areas where high reliability cleaning is required.

Price listings for each style vary from $4 to $175 according to quantity ordered and style. For further information on this product, contact Chemtronics, Inc, 681 Old Willets Path, Hauppauge, NY 11788; tel 800-645-5244, in NY 516-582-3322.

How to Tailor Signal Coverage with Beam Tilt

By Steve Weinstein
Dir of Marketing, Bogner Broadcast Equip Corp
401 Railroad Ave, Westbury, NY 11590[1]

Many engineers in the mobile radio field believe the only way to increase, decrease or improve coverage from a particular site or within a cell is to increase or decrease the effective radiated power (ERP) or to use a directional antenna. Although these are often good ways to achieve a desired coverage pattern, they are not the only ways to do so. By carefully controlling the beam tilt of an antenna, you can obtain results that are much different and, in certain cases, much more effective than simply adjusting the ERP or the horizontal radiation pattern. For example, you can radiate a strong signal, but confine it to a limited area through the use of carefully controlled beam tilt.

Every antenna radiates energy in a particular pattern. Because this pattern is three dimensional, you can look at it from two different perspectives to get a complete picture on paper.

Radiation Patterns

You can take a look at how the antenna radiates horizontally (the horizontal radiation pattern). To do this you could look down on the antenna pattern from above, as though you were hovering overhead in a helicopter. A perfectly omnidirectional antenna (ie, one that radiates equally in all directions) would have a horizontal radiation pattern that looks like a circle.

Directional antennas radiate more power in some directions than in others and can take many shapes, such as a heart shape or peanut shape. In this article, we'll assume the antenna is omnidirectional and concentrate on directing the vertical pattern as a way of tailoring antenna coverage.

The vertical radiation pattern of an antenna is what you would see if you sliced the antenna vertically, as though you were at the same altitude as the antenna and looking towards it. See Fig 1 for an example of a typical published radiation pattern. The lobe at 0 is known as the main lobe and the smaller lobes above and beneath are the side, or minor, lobes. An antenna's gain figure is rated at the peak of the main lobe.

Increasing Peak Gain

One way to increase the peak gain of an antenna is to add more elements to the array. This process has the effect of squeezing the vertical beamwidth to increase the gain at the peak. This procedure is analagous to decreasing the size of a nozzle at the end of a garden hose to make it spray farther. The amount of water remains the same, but covers a larger area. The drawbacks to increasing the gain like this are a narrower main lobe and an increase in the number of side lobes. The disadvantage to a greater number of side lobes is the increase in the nulls, or spaces where there is no signal between these lobes.

In some cases, multipath effects (signal reflections) can provide signal in these nulls. The way to ensure even coverage and eliminate the dead spots caused by these nulls is to incorporate "null fill" into the antenna design. By feeding some of the elements of the antenna with signals of a different amplitude than others, these nulls are "filled" and a more uniform signal coverage is obtained.

Umbrella-Like Effect

The disadvantage of the narrower main lobe is an umbrella-like effect. The narrower beam tends to shoot over the coverage area. If the antenna is mounted at, let's say, a height of 1000 feet above the surrounding terrain, the peak gain of

[1]This article originally appeared in *Personal Communications Technology*, Feb 1986, p 9.

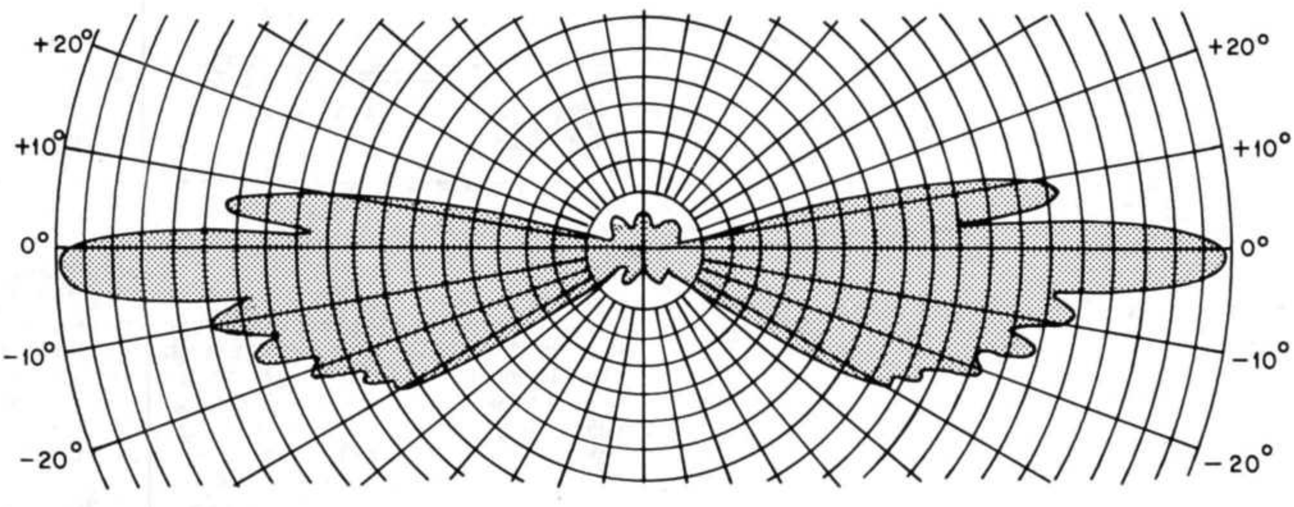


Fig 1— The manufacturers' published antenna pattern can give you a graphic presentation of the antenna's coverage, but it is not accurate enough to calculate coverage contours. (Graphic courtesy of Bogner Broadcast Equip Corp)

the antenna would be 1000 feet up in the air aimed at an angle of 0 degrees.

This gain would always be up in the air, and as distance from the transmitting site increases, the earth curves away from the horizontal, and the peak signal strength is wasted in outer space. The way to avoid this waste and put the peak gain on the ground where it will do some good is to tilt the beam down using beam tilt. The vertical beam can be tilted downwards by physically tilting the antenna (mechanical beam tilt) or by feeding the elements of the antenna array slightly out of phase (electrical beam tilt).

Aiming the Peak of the Beam

By selecting the proper angle that the beam will be tilted downward, you can aim the peak of the beam—where the strongest signal strength is found—at the outer limits of the desired or allowed coverage area, where the strongest signal is needed. This process prevents wasting the strongest part of the signal and sending a good percentage of the surrounding RF energy into outer space. It is wasteful to try to improve the signal strength on the ground by simply switching to a higher gain antenna and then shooting the strongest part of the signal into space.

There can be disadvantages to adding beam tilt to antennas, depending on exactly how the tilt is implemented. Mechanical beam tilt does not electrically lower the vertical beam, as electrical tilt does, but aims the beam downward only in the direction of a physical tilting of the antenna.

This procedure can be acceptable with a very directional antenna, but when used with an omnidirectional antenna, it can be detrimental. In the direction of the mechanical tilt, the beam tilts downwards, but in the opposite direction the beam tilts upwards. Towards the sides there is no tilt—only a slight rotation of the beam.

Uniform Tilt

An electrical beam tilt provides a uniform tilt in all directions by feeding the elements of the antenna slightly out of phase with each other. Using a combination of electrical and mechanical beam tilt can provide different tilts in different directions.

Electrical tilt can have some drawbacks, including a loss of gain due to beam splitting and beam steering. When an antenna's elements are fed from a single feed point (end or center fed) or the antenna's elements are fed in groups and downward beam tilt is introduced by phasing the elements, the main beam begins to "split" and the side lobe at the equal uptilt angle grows larger as more and more tilt is added.

This growing upper lobe robs power from the main lobe, wasting power up into the sky and reducing the peak gain of the antenna. Besides the reduction in peak gain, this upper lobe could cause problems if the radiation were to bounce off the tropospheric atmosphere level (possible under certain weather conditions) and return to earth many miles away in an undesired location.

Eliminating Upper Lobes

Fortunately, feeding the antenna elements individually or in small groups can eliminate this upper lobe. This procedure concentrates the energy in the single main beam that is tilted downward and at the same time keeps the main beam wider, which has the advantage of covering a larger area with higher-strength signals.

Beam steering can be a problem where an antenna array's elements are fed from a single point or in large groups and the antenna is trying to cover a broad frequency band. As an example, end-fed antennas exhibit the worst beam steering.

In this type of antenna, all the antenna elements draw their power from a single point at the bottom or top of the antenna. The individual elements are spaced along a common feed bar or collinear feed strip at precise intervals measured in wavelengths to draw their power from the proper point and radiate at the proper phase.

Wavelength Changes

If the antenna is fed signals at other than the frequency for which it was designed, the corresponding wavelength for the new frequency changes. The spacing between elements should also change.

Because the spacing is fixed, as you go further away from the feedpoint at the new frequency, each element is fed more and more out of phase because of the now-incorrect spacing between elements. Feeding the individual elements slightly out of phase creates electrical beam tilt. Different frequencies used in an antenna of this type, however, produce different beam tilts because the elements are spaced for only a single frequency.

Therefore, at different frequencies, the beam is "steered" up or down. The steering effect is less in a center-fed antenna because the farthest the signal has to travel is half the length of the antenna. Feeding all the elements individually with their own feed lines or in small groups from a central feedpoint with equal length cables or feed bars eliminates this problem.

Signals in Phase

By making all the feed components the same length, no matter what frequency you are using, the signal will reach the radiating elements at the same phase. Slightly changing the lengths of some of these equal length feed lines introduces beam tilt. There is a negligible amount of beam steering in a broadband antenna with electrical tilt when you use this feed method because the feed error is not compounded—ie, feeding the elements one after another in a chain-like fashion.

If you construct the antenna so that the individual feed lines can be accessed, you can adjust the beam tilt in the field. As you may have noticed already, the same solution—using individually fed elements—is the solution to the problems of both beam steering and beam splitting. You have eliminated the problems of beam steering and beam splitting. Now what can you do with this precisely controllable beam tilt?

Published Patterns

First, let's take a closer look at the vertical pattern. Present manufacturers' published patterns give a fairly nice graphic presentation (Fig 1), so you can get a visual feel of what the coverage may be like using that particular antenna. But those patterns are not accurate enough to calculate coverage contours with.

For those purposes, a plot of relative field strength v degrees is much more accurate and suitable (see Fig 2, for example). Relative field strength is a voltage measurement rather than a power measurement and is the square root of a plot of relative power or the antilog of a plot of power in decibels. This process presents a much more detailed and accurate vertical beam plot.

The vertical beam can be tilted downward so that the peak of the beam reaches the ground at the radio horizon. This is, theoretically, the farthest distance at which the signal can reach the ground from a given height above the surrounding terrain.

Covering Maximum Areas

This point is where you need the strongest signal if you want to cover the maximum area. Aiming the vertical beam peak at the radio horizon may not be desirable for two reasons:

First, most radio systems do not have enough power to reach that far with an adequately strong signal. At a 1000-foot height, the radio horizon is approximately 45 miles away.

Second, this process wastes a lot of power between the peak and the half power point on the upper side of the beam. It is desirable to put all of the antenna's strongest signal onto the ground rather than wasting it where there are no receivers.

If you continue increasing the amount of beam tilt, you can aim a particular point on the upper side of the beam with a specific relative field strength at a given point. For example, you could aim the upper half-power point at the radio

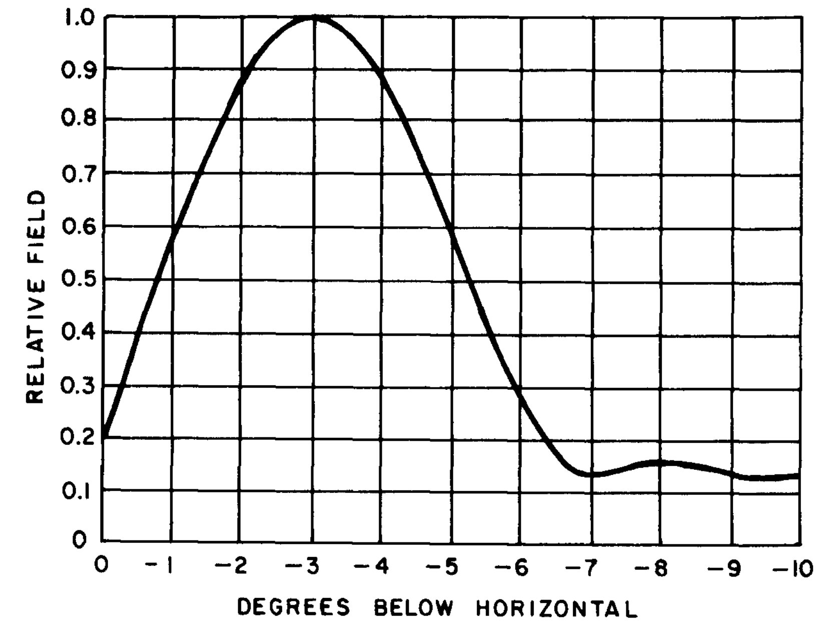


Fig 2—A plot of an antenna's relative field strength v degrees below horizontal provides an accurate method of calculating the antenna's coverage pattern. (Graphic courtesy of Bogner Broadcast Equip Corp)

horizon instead of into space.

Increasing Signal Strength

This technique can be used to increase the signal strength within a system's allotted coverage area (or cell in cellular radio applications) without increasing the size of the coverage area or radiation levels towards neighboring systems (or cells). It can also be used to reduce signal levels or interference with neighboring systems without losing any signal strength within your own system.

In cellular applications, you could add an extra cell to a system to fill in a dead signal area or to provide strong coverage within a particular area such as the downtown section of a large city, where you need a strong signal to penetrate buildings and reach the new generation of lower-powered portable radios or pages in a paging system.

For example, look at Fig 2 again. At a height of 1000 feet above the average terrain (HAAT) and a beam tilt of minus 3.0 degrees (as shown), the peak of the beam will hit the ground at a distance of approximately 3.6 miles from the site. At an angle of minus 1.4 degrees, the signal will reach the ground at a distance of 7.75 miles. The relative field strength at that angle is approximately 0.7. The relative power at that point is $(0.7)^2$ or 0.49, which is approximately the half power point, or 3 dB down point.

Strongest Signal

As another example, suppose you want the strongest possible signal strength within a radius of 12 miles, but have to be at least 10 dB below that level outside the 12-mile radius. Ten dB down is equal to a relative field strength of approximately

$$0.316 \cong \left(\sqrt{10^{-10dB/10}}\right) \quad \text{(Eq 1)}$$

(To convert relative field to dB down: 20 log (rel field) = dB down.) From your 1000 foot HAAT, the 12-mile point occurs at minus 0.9 degrees.

If you adjust the beam tilt of the antenna so that the 0.316 relative field strength level occurs at minus 0.9 degrees, you then have your strongest signals within the 12-mile radius and 10 dB down at 12 miles with the signal strength falling off rapidly beyond that distance as the relative field strength drops off at higher angles.

As you can see from the above examples, you can use beam tilt to improve coverage if you calculate and implement the system carefully. You should exercise caution when mounting the antenna. As you can see in Fig 2, making a small increment in beam tilt can result in a large change in signal strength at a particular point.

High Gain, Narrow Beam

The higher the gain of the antenna you use, the narrower the vertical beamwidth and the steeper the slope on either side of the beam peak. For this reason it is important that you mount the antenna rigidly and exactly vertical. Otherwise, unintended mechanical beam tilt could change the desired results.

With a properly mounted antenna and the right amount of beam tilt, you can improve coverage in many systems or cells. Existing signal strength problems can be easily cured—inexpensively and effectively.

Steve Weinstein is the director of marketing for Bogner Broadcast Equip Corp. He has a BS in engineering from Hofstra University and a JD degree from Brooklyn Law School. He has been with Bogner since 1979 and was instrumental in introducing the company's 800/900-MHz antennas for mobile radio, paging and cellular base stations.

Bits

RF Expo East

RF Design Magazine is sponsoring its first east coast conference for RF engineers on November 10-12, 1986 at the Boston Marriott Copley Place. The technical program is composed of 60 original papers, including the 12 most popular titles from EXPO 86 and the three top entries of the first RF Design Awards Contest. Session topics include SAW Devices, Power Amplifiers, Digital Interfacing, Filter Design, Medical Applications of RF and Computer Aided Design II. Over 100 RF manufacturers will feature exhibits.

RF Design encourages engineers who are also Amateur Radio operators to bring their 2-m handheld transceivers to the conference. The operating frequency will be posted at the registration area of the show.

Register for RF Expo East in advance and qualify for substantial discounts on airfare, hotel and other accommodations.

For further information on the schedule of technical sessions and a registration form, contact *RF Design*, 6530 South Yosemite St, Englewood, CO 80111.—Gary Breed, K9AY, Technical Editor, *RF Design*

Padding Calculations Made Easy

By Jacob Z. Schanker, W2STM
65 Crandon Way
Rochester, NY 14618

Each time you set out to build a VFO or receiver, how do you determine the amount of padding capacitance required to get a desired tuning range with the variable capacitor you have available? Most hams resort to a cut-and-try method. This makeshift approach isn't necessary. A little manipulation of some basic equations yields simple formulas that give the exact amount of padding required.

A resonant circuit consisting of a variable capacitor, a padding capacitor and a coil, takes either of the two basic forms shown in Fig 1. Whether the parallel form or the series form is most useful depends on the specific application. Often one form will yield reasonable component values, while the other gives outrageous ones, as the example will show. The equations required to calculate the padding capacitance and the coil inductance will be introduced as we go through a practical example. To conclude, the short BASIC computer program given will readily calculate needed values.

A Practical Example

Let's build a tuned circuit (for a VFO, for example) to cover 7.0 to 7.3 MHz. A variable capacitor, which has a range of about 12 to 60 pF, was salvaged from an old capacitor Q multiplier in our junk box. We first determine if the value of the padding capacitance is in series or is parallel. Then, the value of the coil is calculated so that the 7.0- to 7.3-MHz frequency range is spread out over the whole range of the variable capacitor.

First, we calculate the ratio (F) of the highest to the lowest frequency in the desired coverage range:

$$F = \frac{f_{max}}{f_{min}} \qquad \text{(Eq 1)}$$

here,

$$F = \frac{7.30}{7.00} = 1.0429 \qquad \text{(Eq 2)}$$

The familiar resonance equation,

$$f = \frac{1}{2\pi\sqrt{LC}} \qquad \text{(Eq 3)}$$

shows us that the resonant frequency varies as the square root of the capacitance, therefore, our ratio of maximum to minimum capacitance must vary as the square of the ratio of maximum to minimum frequency, F.

Calling the capacitance ratio required R, we have:

$$\frac{C_{max}}{C_{min}} = R \text{ then, } R = (F)^2 \qquad \text{(Eq 4)}$$

and in our example,

$$R = (10429)^2 = 1.0876 \qquad \text{(Eq 5)}$$

Note that while we require a ratio $C_{max}/C_{min} = 1.0876$, the available variable capacitor has a ratio $C_{max}/C_{min} = 60/12 = 5$. The effect of a padding capacitor is to reduce this value to the required ratio of 1.0876.

For parallel padding, the value of the required padding capacitor C_p is given in Eq 6:

$$C_p = \frac{C_{max} - C_{min} \times R}{(R - 1)} \qquad \text{(Eq 6)}$$

and in our example,

$$C_p = \frac{60^{-12} \times 1.0876}{(1.0876 - 1)} \qquad \text{(Eq 7)}$$

$$C_p = 536 \text{ pF.}$$

This is a reasonable value of capacitance and might consist of a fixed mica or polystyrene capacitor somewhat smaller than 536 pF in parallel with a small trimmer. As a check on the equations, note that since the capacitors in parallel add,

$$\frac{C_{max}}{C_{min}} = \frac{60 \text{ pF} + 536 \text{ pF}}{12 \text{ pF} + 536 \text{ pF}} = \frac{596 \text{ pF}}{548 \text{ pF}}$$

$$= 1.0876 \text{ as desired.} \qquad \text{(Eq 8)}$$

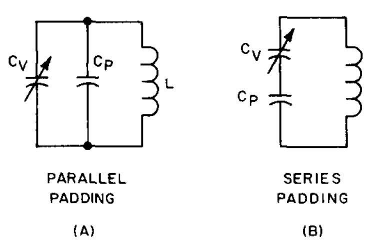


Fig 1—In A, the resonant circuit consists of a variable capacitor, a padding capacitor and a coil wired in parallel. B shows the components in a series configuration.

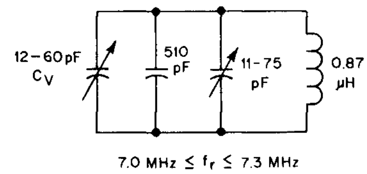


Fig 2—This tuned circuit covers a frequency range of 7.0 to 7.3 MHz. The component values were determined by using the equations in the text.

To calculate the coil inductance required, we use the resonance formula rearranged to solve for L.

$$L = \frac{1}{(2\pi \times f_{min})^2 \times C_{max}} \qquad \text{(Eq 9a)}$$

or,

$$L = \frac{1}{(2\pi \times f_{max})^2 \times C_{min}} \qquad \text{(Eq 9b)}$$

solving using (9a):

$$L = \frac{1}{(6.28 \times 7.0 \times 10^6) \times 596 \times 10^{-12}}$$

$$L = 0.87\ \mu\text{H} \qquad \text{(Eq 10)}$$

For those uncomfortable with scientific notation (exponents), equations 9a and 9b may be rewritten as

$$L(\mu\text{H}) = \frac{25{,}330}{(f_{min} - \text{MHz})^2 \times C_{max} - \text{pF}} \qquad \text{(Eq 11a)}$$

or

$$L(\mu\text{H}) = \frac{25{,}330}{(f_{max} - \text{MHz})^2 \times C_{min} - \text{pF}} \qquad \text{(Eq 11b)}$$

Try these equations to confirm that they all result in the same answer.

Our circuit then, might look like that shown in Fig 2. Note that a trimmer capacitor is used as part of the padding capacitance to compensate for stray capacity and component tolerances.

Now what about using a series padding arrangement? For series padding:

$$C_p = \frac{(R - 1)}{\frac{1}{C_{min}} - \frac{R}{C_{max}}} \qquad \text{(Eq 12)}$$

Solving for our problem:

$$C_p = \frac{(1.0876 - 1)}{\frac{1}{12} - \frac{1.0876}{60}} = 1.34 \text{ pF}$$

(Eq 13)

This is an impractically small value of capacitance, and so series padding cannot be used in this problem. There may be situations, however, where series padding would be used in preference to parallel padding. Working the equations for both parallel and for series padding will, in most cases, quickly show which is the most practical.

The secret formulas have been revealed. Tuck them away in a safe place and save yourself lots of grief the next time you build a tuned circuit.

Table 1

BASIC Program For Calculating Padding Values

```
10  REM ** PADDING CALCULATIONS
11  REM ** MADE EASY
12  REM ** BY J.Z. SCHANKER
30  PRINT "ENTER DESIRED MAX. FREQ. (MHZ): ";: INPUT FH
40  PRINT "ENTER DESIRED MIN. FREQ. (MHZ): ";: INPUT FL
50  F = FH/FL
60  R = F * F: REM REQUIRED CAP. RATIO
70  PRINT "ENTER DESIRED MAX. CAP. (PF): ";: INPUT CH
80  PRINT "ENTER DESIRED MIN. CAP. (PF): ";: INPUT CL
90  IF (CH/CL) x R THEN PRINT "INADEQUATE CMAX/CMIN RATIO": GOTO 70
100 CP = (CH - CL * R)/(R - 1)
120 PRINT "PARALLEL PADDING CAPACITANCE (PF)= ";CP
130 L = 25330/((FH * FH) * (CL + CP))
140 PRINT "REQUIRED INDUCTANCE (UHY)= ";L
150 CS = (R - 1)/((1/CL) - (R/CH))
160 PRINT "SERIES PADDING CAPACITANCE (PF)= ";CS
162 CM = 1/((1/CS) + (1/CL))
164 L = 25330/((FH * FH) * CM)
166 PRINT "REQUIRED INDUCTANCE (UHY)= ";L
170 PRINT
180 PRINT "ENTER NEW CAPACITANCE RATIO (Y/N)? ";: INPUT A$
190 IF LEFT$ (A$,1) = "Y" THEN 70
200 END
```

Bits

Be an Author

Have you ever considered writing for *QST* or *QEX*? If you have an article in mind—or on paper or on disk—we've got the publication that will give it the best exposure to the Amateur Radio community. And now there's still another reason to think first of *QST* or *QEX*: The ARRL Board of Directors has authorized payment for articles published in either of these two periodicals.

Want more information? Write ArtInfo, Dept SR, ARRL HQ, 225 Main St, Newington, CT 06111.

Copy Data From UoSAT-1 and UoSAT-2

Two satellites that have not received much attention in the US are UoSAT-OSCAR 9 and UoSAT-OSCAR 11. Designed and built by the University of Surrey in England, the satellites are intended to provide a tool to schools who wish to learn more about satellites. The beacon on 145.825 MHz provides ASCII data that can be decoded with your computer.

James Miller, G3RUH, has designed a demodulator for the two UoSAT birds. To my knowledge, the circuit diagram has appeared in several overseas journals, but not in a US publication. The circuit board is available at a fair price and is sent in a well-padded envelope. An abbreviated article by AMSAT-UK accompanies the circuit board. Send an SASE with several IRCs to AMSAT-UK, London, E12 5EQ, England, United Kingdom.

Almost all but one of the components can be purchased from Radio Shack or Dick Smith Electronics. I had difficulty locating the "divide by 16" IC, but had success at a local Motorola distributor.

To align the demodulator, only one tunable filter must be set. I first inserted a "blown" PLL chip on my board, but that was easy to spot because I was receiving no output. Once a new chip was inserted, everything was go.

To receive the ASCII data from the UoSAT birds, you will need a 2-m receiver, the G3RUH UoSAT decoder, a computer and a good terminal program. My station consists of a TS-700A, dual KLM 14C antennas, a C64 computer with an MFJ RS-232-C board and the "Plus/Term" program from the Feb 1985 issue of *Compute* magazine.

If you have never seen the data contained on the UoSAT beacons, you are in for a pleasant surprise. Lengthy bulletins equivalent to an issue of the *Amateur Satellite Report* or the ARRL bulletins are transmitted. Additionally, Keplerian elements are updated weekly. Similar to OSCAR 10 operation, satellite parameters are also given.

Frankly, I must admit that prior to building the UoSAT demodulator, I listened to these satellites on rare occasions. Now that I am able to demodulate the data, it is regular practice for me to listen in and retain the information on file for future reference.

If you wish to build the UoSAT demodulator, I will be happy to provide advice. If you experience problems, include an SASE with your letter. Otherwise, a note to G3RUH, with several IRCs will deliver a prompt response from him.—*Ross Forbes, WB6GFJ, PO Box 1, Los Altos, CA 94023-0001*

Assorted Caps to Fit the Occasion

Voltronics offers a wide line of precision trimmer capacitors for crystal oscillators, filters, radio, transmitters and many other applications. Features of the company's product include better linearity, lower inductance, smaller size, higher stability and a longer life than that of its conventional counterpart. Designs are manufactured from glass, quartz, teflon, sapphire and air dielectrics. Sapphire's dielectric constant does not change with frequency, it is chemically inert, moisture resistance and mechanically strong. Its dielectric loss tangent is constant and below 0.0003 up to 10 GHz, thus this trimmer capacitor is ideal for UHF and microwave applications. New surface-mount microwave trimmers are suitable for high-shock conditions and vibration. Engineering prototyping kits are also available. For a catalog, write to Voltronics Corp, PO Box 476, East Hanover, NJ 07936.—*KA1DYZ*

Crystal Oscillator for Digital Circuits

By Paul Newland, AD7I
PO Box 205
Holmdel, NJ 07733

Several oscillators that use logic gates have been built for different projects I designed. Virtually, I have been unhappy with the performance of each. Often the oscillators consume too much power, force the crystal to dissipate too much power, stimulate the crystal with signals of high harmonic content, and so on. The circuits worked, but they were hardly ideal.

But now, thanks to high-speed CMOS (HCMOS), designing oscillators for digital systems is a breeze. Fig 1 shows an oscillator that I have used with great success. Radio amateurs will recognize it as a standard Colpitts oscillator.

The Colpitts oscillator has an interesting feature. If the transistor's base is biased to half the supply voltage, the sine wave's positive excursions are, approximately, the supply voltage and the negative excursions are, approximately, ground. These are the correct voltage levels for HCMOS parts.

If the input of a Schmitt-trigger inverter is connected to the base, a square wave is produced at the output of the inverter. The input of the inverter has about 5 pF of capacitance to ground, but this doesn't significantly alter oscillator operation—the 5 pF is swamped out by the much larger values of C3 and C4. Unlike other logic families, the 5-pF capacitance is the only loading that the driving circuit sees; there is no significant dc current flowing into or out of the inverter. HCMOS will work from dc up to 20 MHz. The circuit was used at 4 and 10 MHz, but should operate well at other frequencies.

With crystals cut for parallel resonance at 20-pF loading, setting C1 for about 25 pF brings the oscillator right on frequency. Alternatively, if fine-frequency control is not needed, do the following: remove C1, short out C2 and use crystals cut for 32-pF loading. The circuit drives the crystal with a sine wave and consumes less than 5 mA. Finally, the clock signal output swings from the supply voltage to ground. Thus, it is suitable for logic elements that require clocks to go to within 0.5 volts of the supply voltage (like the Z80® microprocessor family of parts).

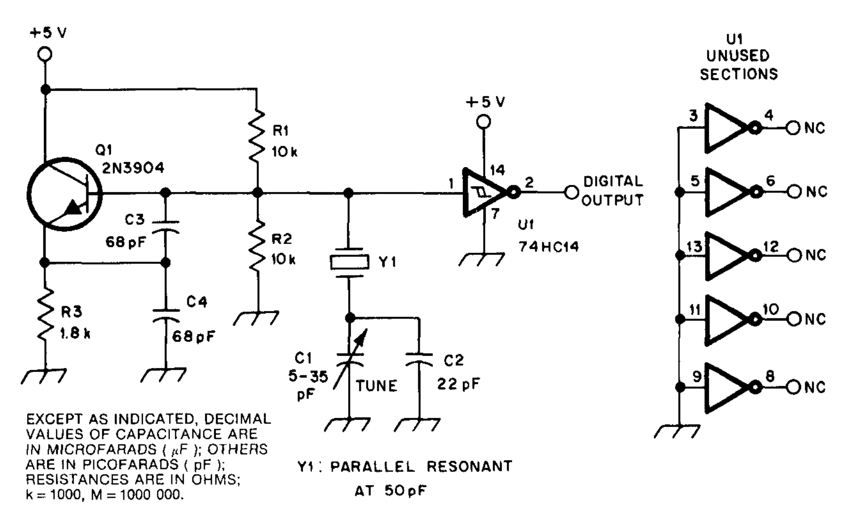


Fig 1—The schematic diagram of the oscillator. The circuit provides a digital output and draws low current (typically 3 mA). It can be adjusted easily for exact frequency operation and the crystal drive signal is a sine wave instead of a square wave.

Bits

OSCAR 10 Satellite Accessory Available From Project OSCAR

PLAN10, one of the most popular OSCAR tracking programs outside the US, is now available in North America. Developed by James R. Miller, G3RUH, PLAN10 has proven to be the premier tracking program (without graphics) for OSCAR-10 users.

PLAN10 was the first program to give details on when satellite operating conditions are the best during each orbit! The program supplies antenna pointing information, calculates where OSCAR is pointed during each orbit, and gives details on when the satellite is in sunlight, twilight or total eclipse. The OSCAR-10 user can now understand why attitude changes are made, and study the effects future changes will have on general operating conditions.

Some knowledge of editing a BASIC program is required. The program is not copy protected, and can be listed.

PLAN10 is available on disk for the C64, C128 (in the C64 mode), VIC 20, TRS-80 (I/III) IBM®, Apple® IIe and IIc, CP/M®. The CP/M version comes on an eight-inch disk.

Cost is $20 per disk and is available from PLAN10, Project OSCAR, Inc, PO Box 1136, Los Altos, CA 94023-1136. All funds received from PLAN10 sales are directed toward future satellite construction.—*Ross Forbes, WB6GFJ, PO Box 1, Los Altos, CA 94023-0001.*

Xerox 820-1 Compendium—Part 4

By Dave Borden, K8MMO,
AMRAD, PO Drawer 6148, McLean, VA 22106-6148

More on Packet ICOM-2AT Xerox 820-1 Connection

Let's continue to learn more about Xerox 820-1 applications for the computer ham shack.[30] I hooked the user parallel port to my ICOM-2AT 2-meter hand-held transceiver and was able to control the transmit and receive frequency; the ICOM acted similar to a scanner. I hope to accomplish frequency hopping using my equipment as a spread-spectrum receiver to snatch the elusive AMRAD beacon out of the airwaves. My project was completed in four hardware stages. First, the ICOM connection.

Hardware Stage One—The ICOM Socket

I cut a rectangular hole in the back of my ICOM 2-meter radio to hold a 16-pin socket. Do not do this if you want to continue using the radio in the traditional handheld service (riding around on your belt). The socket is glued to the back of the unit using model cement. Fig 2 shows the wire connections that are added to the 16-pin socket inside the hand-held transceiver. An alternative method is to bring a ribbon cable out the side of the radio. Either method works, but you have to connect the wires to the IC-2AT to change the frequency by computer. Twelve wires go to the small PC board inside the radio. The board is recognizable because a cable runs from it to the thumbwheel switches at the top of the compartment; we parallel it. You may also want to cut the wire that ties the 4-MHz line high and add an 8-MHz solder bridge while you are working in this area. This is a good idea—we do not want the thumbwheels to control certain functions simultaneously with the Xerox.

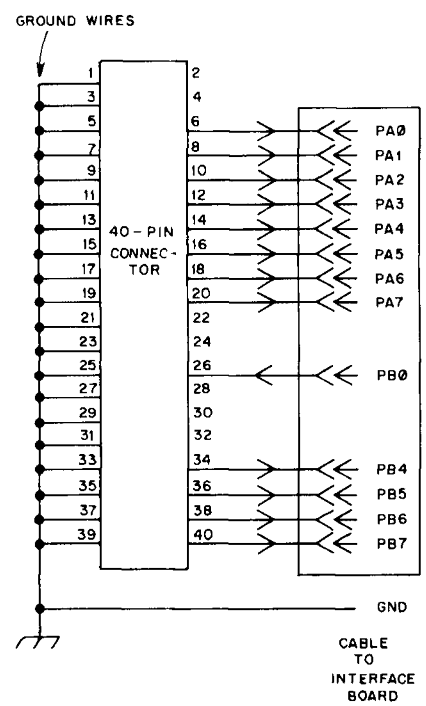


Fig 3—The 16-pin connector cable is wired from the Xerox at point J8 to the interface board. The ground wires must be added because Xerox omitted them.

What we have here are three BCD digits, four binary lines each. When a line is tied high (+5 V), that line is selected. The first BCD digit is MHz, the second is hundreds of kHz and the third is tens of kHz. While you are inside the transceiver, connect the squelch mute line (wire 13), ground (wire 14), and the 5-kHz line (wire 15) to the 16-pin socket. Leave one spare socket pin for future expansion. Next, use a 16-pin cable with DIP plugs at both ends to connect the 2-meter transceiver to the interface board.

Hardware Stage Two—Cable to Xerox

Obtain a 40-pin, 0.1 CTR Contact Socket connector (female). These connectors are available in grab bag type packages. This is plugged into the Xerox board at J8. Pin connections are shown in Fig 3. The 16-pin ribbon cable is wired from J8 to the interface board.

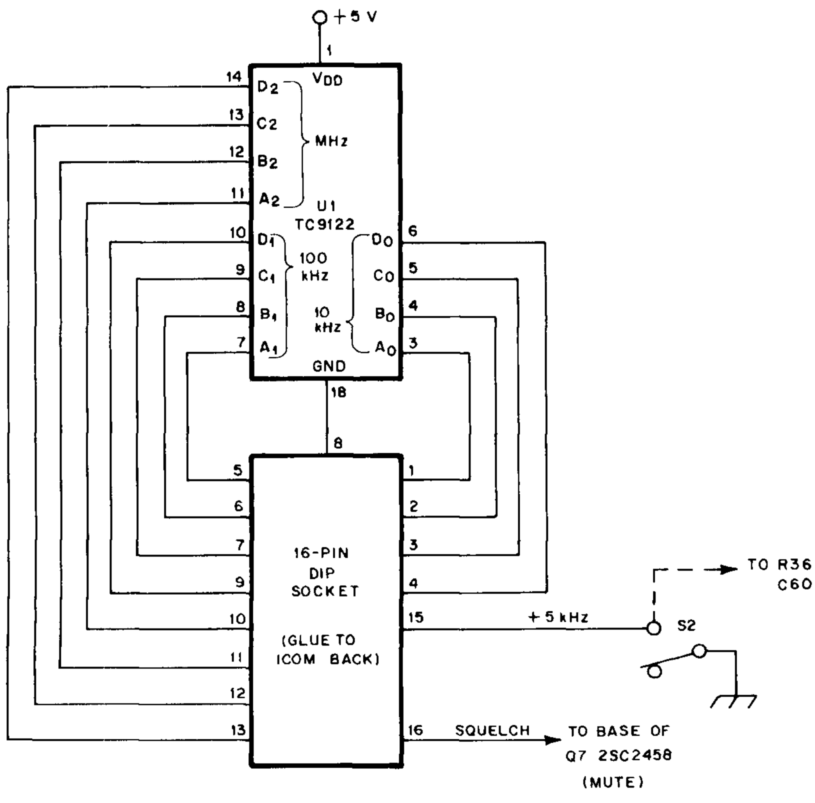


Fig 2—An ICOM IC-2AT is a perfect candidate for connecting the Xerox 820-1 board to for use on packet. The connections enable the hand-held transceiver to control the transmit and receive frequency when using the 820-1 with a computer.

Notes appear on p 13.

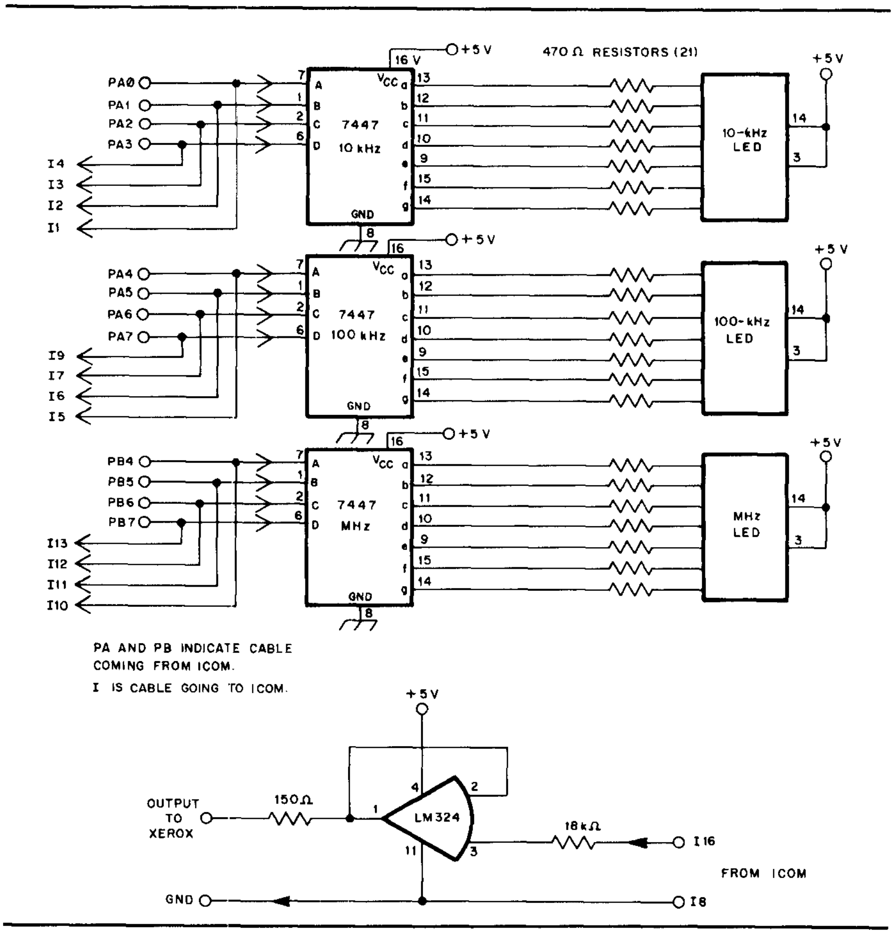


Fig 4—A frequency display board connected between the Xerox and IC-2AT tells the user where he or she is operating.

Hardware Stage Three—The Interface Board

Fig 4 shows a frequency display board I built from Radio Shack parts. Basically, the BCD digits I mentioned earlier are displayed. You must set the IC-2AT's thumbwheels to 000 (to prevent burning up your rig) and control the frequency from Xerox software, otherwise you may not know what frequency you are operating on. Elton "Sandy" Sanders, WB5MMB, dreamed up this gadget which he calls the ICOM simulator. It was to be used in place of the hand-held transceiver until the software was running correctly. I leave my unit in the line between the radio and the Xerox at all times to display the current frequency. The gadget simplifies the software. I added the op amp to read the squelch line and report any found signal to the Xerox for the software to look at. The frequency display could be eliminated and the frequency displayed on the Xerox monitor screen instead.

Port Initialization Software

You can use different kinds of software with this project. I first used Microsoft BASIC. The Xerox 820 PIO user port is initialized as follows:

```
10 REM INIT XEROX 820 GENERAL
   USER PARALLEL PORT
20 REM SET PORT A TO BIT MODE
   (MODE 3)
30 REM 110001111
40 OUT 9,2007
50 REM SET PORT 1 TO ALL OUTPUT
   BITS
60 REM 0000000
70 OUT 9,0
80 REM DISABLE INTERRUPTS ON
   PORT A
90 REM 010000000
100 OUT 9,64
110 REM SET PIO PORT B TO BIT
   MODE (MODE 3)
120 REM 11001111
130 OUT 11,207
140 REM SET PORT B TO UPPER
   OUTPUT LOWER INPUT
150 REM 00001111
```

DIGITAL DEVELOPMENT CONTINUED...

```
160 OUT 11,15
170 REM DISABLE INTERRUPTS ON
   PORT B
180 REM 01000000
190 OUT 11,64
200 REM CLEAR ALL LINES
210 REM 00000000
220 OUT 8,0
230 REM 00000000
240 OUT 10,0
250 PRINT "INTIALIZATION OF THE
   PIO HAS OCCURRED"
260 STOP
```

After turning on the Xerox board and IC-2AT, run this program to initialize the PIO. Be ready to control the frequency.

Hand Setting Frequency Software

The following program allows me to hand set my transceiver to the desired frequency. Do not forget that the transceiver's thumbwheels are set to 000 for these tests! Failure to do so could result in a fried radio as both the thumbwheel's 5 volts and the computer's 5 volts attempt to set the frequency simultaneously.

```
   5 PRINT "AMRAD XEROX ICOM
     HAND SET PROGRAM"
  10 PRINT "ENTER MHZ-"
  20 INPUT MEGA
  30 PRINT "ENTER KHZ-"
  40 INPUT HUN
  45 PRINT "ENTER KT-"
  50 INPUT KT
  55 GOSUB 1000
  60 GOTO 5
1000 MH = MEGA*16
1010 KH = HUN*16
1020 KH = KH + KT
1030 OUT 10,MH
1040 OUT 8,KH
1050 RETURN
```

Scanner Software

The following program scans the 146.00- to 147.99-MHz frequency range to look for active signals. When one is found, the program stops for eight seconds and samples the find, then moves on. Stop the program with a Control-C and enter a small number (ie, 10)for "speed" if you want fast scanning. Enter a big number (like 200) if you want slow scanning. I discovered one drawback. When an active signal is detected, the radio stops for eight seconds, then continues, but there is a squelch tail. Thus, the next frequency to be detected, whether active or inactive, is also sampled and many an eight seconds may be wasted. Some software changes are called for to correct this problem.

```
 10 PRINT "AMRAD XEROX ICOM
    SCANNER PROGRAM"
 20 PRINT "SPEED="
 30 REM SPEED IS THE AMOUNT TO
    DELAY BETWEEN HOPS
 40 INPUT SPEED
 50 REM SAMPLE 146.00 TO 147.99
 60 FOR MEGA = 6 TO 7
 70 FOR HUN = 0 TO 9
 80 FOR KT = 0 TO 9
 90 REM GO OFF AND SET THE ICOM
    TO DESIRED FREQ
100 GOSUB 210
```

```
110 REM NEW FREQ NOW SET, WAIT
     HERE "SPEED"
120 FOR Y = 1 TO SPEED
130 NEXT Y
140 REM DELAY OVER, SAMPLE
     SQUELCH FOR SIGNAL
150 GOSUB 280
160 IF (SIGNAL=1) THEN GOSUB 330
170 NEXT KT
180 NEXT HUN
190 NEXT MEGA
200 GOTO 60
210 REM SET THE ICOM TO THE
     DESIRED FREQ
220 MH = MEGA*16
230 KH + HUN*16
240 KH = KH + KT
250 OUT 10,MH
260 OUT 8, KH
270 RETURN
280 REM SAMPLE SQUELCH LINE
     FOR SIGNAL
290 SIGNAL = INP(10)
300 REM MASK OFF THE MEGAHERTZ
     OUTPUT PART
310 SIGNAL = SIGNAL AND 1
320 RETURN
330 REM SIGNAL DETECTED,
     ANNOUNCE FREQ AND DELAY
340 PRINT MEGA, HUN, KT
350 FOR Z = 1 TO 2000
360 NEXT Z
370 RETURN
```

A FAD and A Modem

By Terry Fox, WB4JFI, AMRAD

TAPR has available an 8530 SCC (serial-communications controller) daughterboard for the Xerox 820-1.[31] It is called the *frame assembler/disassembler*, or FAD board. This board replaces the spare PIO on the 820.

The FAD board is not for everyone. It requires some modification of the 820 board and is handy for those who write code for the SCC for other devices (such as the PAD and IBM HDLC boards). TAPR has made the daughterboard available to aid in network development. Some operators will want to use the FAD, while others may wish to use the NRZI circuit K8MMO described in Part 3.

A Modem for the FAD

Fig 5 shows how to interface the AMD7910 World-Modem Chip® to either the 8530 SCC or the Zilog SIO. It assumes a direct connection to the SCC or SIO, not RS-232-C. This is the interface I use on my Xerox 820-1 board and it has a FAD board installed. I put the modem circuitry in the kludge area of the FAD board to conserve space.

Most of the interface circuit is based on the one in *The 1985 ARRL Handbook*. The serial signals are TTL levels directly from the SCC or SIO. If the modem is used with the FAD board, the modem clock (X1) can be derived from the SCC clock (pin 26, TRXC). If the modem is to be used with the SIO or another application where 2.4576 MHz is not available, a crystal of that frequency should be placed between X1 and X2. (It may be necessary to add two 15 pF capacitors, one between each end of the crystal and ground for stability.)

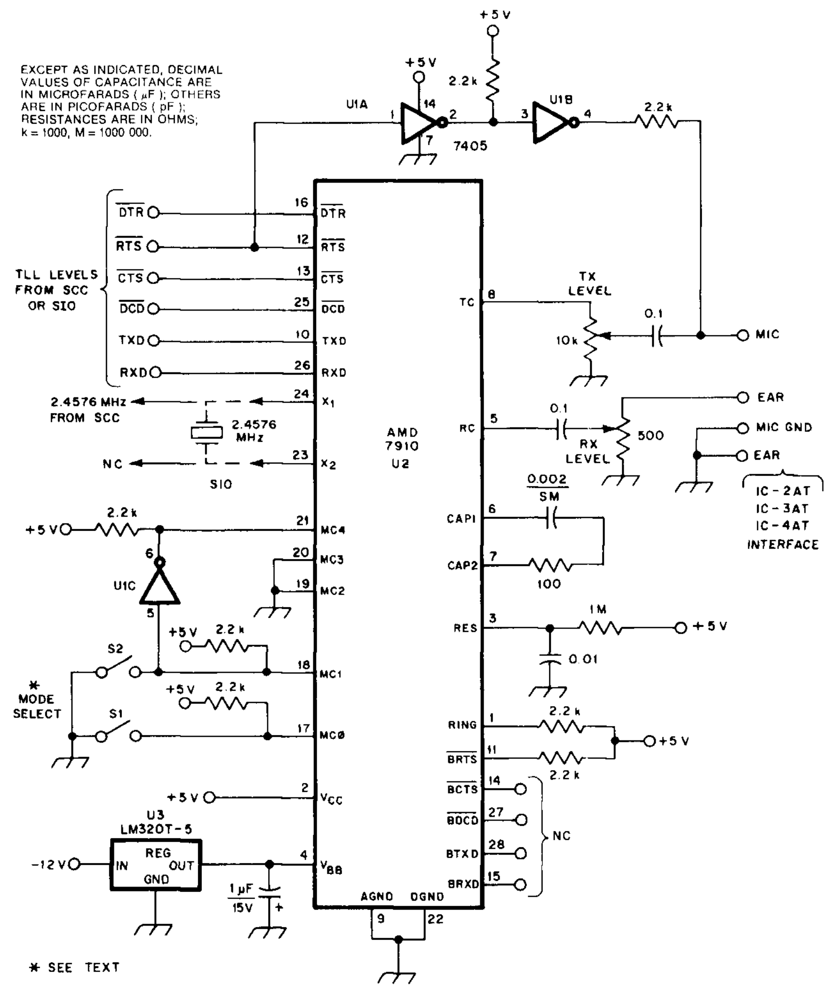


Fig 5—The schematic diagram shows how to interface the AMD7910 World- Modem Chip to either an 8530 SCC or a Zilog SIO.

S1 and S2 are used to determine the mode of operation of the modem chip. S2 determines whether the modem operates in the Bell 103 (closed) or the 202 (open) mode. In the 103 mode, the modem is placed in loop-back operation to allow the same tones to be used for both transmit and receive. In the 103 mode, S1 is used

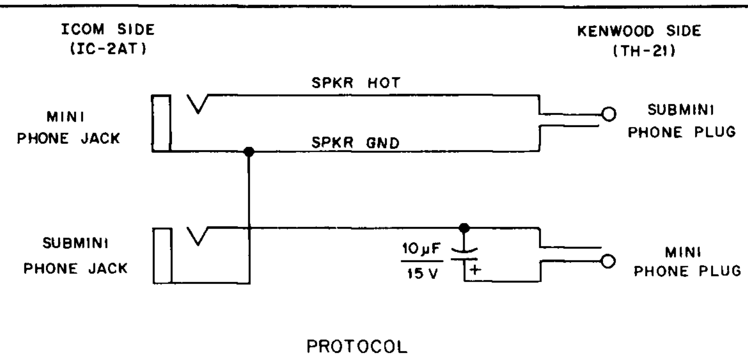


Fig 6—An ICOM-to-Kenwood interface.

to determine whether originate (closed) or answer tones (open) are used.

When S2 is open, the 202 mode is selected. In the 202 mode, S1 is used to enable/disable frequency equalization. I haven't determined that this makes much of a difference, so I leave S1 on; this switch position turns off the equalization.

The output interface drives an ICOM IC-2AT type radio. I use a Kenwood TH-21AT for my main radio, delegating my IC-2AT to packet work. Since I normally use the IC-2AT, most of my packet systems have ICOM interfaces. One day I was stuck with just the Kenwood HT, and had to devise a way to make it packet. In addition to the connectors being backwards, the Kenwood uses a different microphone interface. Fig 6 shows the ICOM-to-Kenwood translator I used. It looks strange, but it works.

I now send and receive frames using the FAD board with the described modem. The only requirement is that the radio used have a squelched speaker line, otherwise the 7910 carrier detect finds a carrier all the time in the noise.

Double-Sided Disk Drive BIOS Information

When you obtain a CP/M® system to run on your Xerox 820-1, and if you are intent on using 5¼ inch disk drives, check your BIOS (Basic Input/Output System) for single- or double-sided drives. You may have an old BIOS that only does double-sided drives by the A B C D system (80 kbytes per drive) instead of two large drives (170 kbytes per drive). To get the correct configuration, check your disk parameter block and header table. They may require modification.

[In our next installment, Dave Borden, K8MMO, relates to us his experiences with Fred and PACANSWR.]

Notes

[30]Parts 1 through 3 of this article appear in *QEX* issues for June, July and August 1986.

[31]TAPR, PO Box 22888, Tucson, AZ 85734

Bits

Instruments for Telecommunications

The Intelco 600. . .T1/DS1 Handheld Bit-Error-Rate Analyzer is ideal for field workers who analyze digital T1/DS1 equipment, circuits and repeaters within either telecommunications service or end-user environments. The handheld features microprocessor control of all test functions, liquid-crystal displays, and over 25 error measurement and analysis functions. Intelco was founded in 1985 to design, develop and manufacture state-of-the-art, high-performance test equipment for fiber optic and high speed digital telecommunications customers.

Information about the T1/DS1 Handheld BER Analyzer and a catalog of Intelco's 1986 products can be obtained by contacting them at 8 Craig Rd, Acton, MA 01720; tel 617-264-4485. A quarterly newsletter entitled *Lite Rate* is also available to qualified candidates. Each issue features technical information about testing fiber optic and digital telecommunications systems.—*KA1DYZ*

Fiber Optic Literature Available

Allied Corp publishes a catalog of Amphenol® fiber optics products. What is different about their advertising literature, however, is that a fiber optic designer's handbook is part of the package. Introductory information about this technology, its data link, how to select and terminate a fiber optic cable, a glossary of terms, and much more make up the 30-page booklet. If you or your company are considering the advantages of using fiber optics, reading this booklet will only convince you that you are headed in the right direction. Write to Allied Amphenol Products, 4300 Commerce Court, Lisle, IL 60532; tel 312-983-3500.—*KA1DYZ*

Where's Your Pad?

Are you planning on shipping merchandise? What about the corners of that unit? Will shipping mishaps toss the contents of that box around resulting in damaged corners? Why not protect your stock with corner and edge polyfoam packaging? For a catalog of what's available, write to Polyfoam Packers Corp, 2320 S Foster, Wheeling, IL 60090; tel 312-398-0110. —*KA1DYZ*

Hirose—The Ideal Connection

Whether you will be working with fiber optics, microwaves, computers or any other electronic application, note that Hirose Electric USA, Inc, features a host of connectors for many applications. Twelve different catalogs are available. Choose the one associated with the area of research you are working with. Write Hirose Electric USA, Inc, 9254 Deering Ave, Chatsworth, CA 91311. Let them be your creative link to world electronics.—*KA1DYZ*

Industrial Devices Will Light Up Your Life

If you are seeking a specific type of indicator light, you are certain to locate it in the catalog published by Industrial Devices, Inc, of NJ. Ordering information on LEDs in all shapes and sizes, relampable and non-relampable indicator lights, and much more is yours when you request *The Source for Indicator Lights* catalog from Industrial Devices, Inc, Edgewater, NJ 07020; tel 201-224-4700. Custom products and an engineer's kit that contains 28 LEDs, their assemblies, nine sockets and so on are also available. —*KA1DYZ*

More Power in Less Space

MWS® Wire Industries has developed Microsquare™ magnet wire for specialty coil and motor windings. If your project has a space crunch, this film coated magnet wire enables you to design compact coils that deliver more power in less space. Miniature square and rectangular, copper and aluminum wire is available in a wide range of solderable and high-temperature insulations in a variety of colors, with or without bondable overcoats. Custom wires are produced in sizes smaller than 14 AWG or 3500 sq mil cross-sectional area. For further information and a free technical data booklet, contact MWS Wire Industries, 31200 Cedar Valley Dr, Westlake Village, CA 91362; tel 800-423-5097, in CA 800-992-8553, and in LA 818-991-8553. —*KA1DYZ*

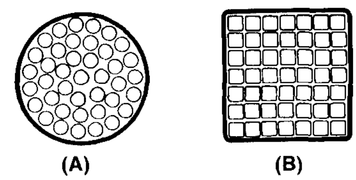


Illustration of cross-section of typical coil winding using round magnet wire (A). Illustration of cross-section of coil winding using MWS Microsquare magnet wire demonstrates improved winding uniformity and maximum use of space (B). *(graphic courtesy of MWS Wire Industries)*

>50
Focus on technology above 50 MHz

By Bill Olson, W3HQT
Box 1655A, RFD 1
Burnham, ME 04922

Chip Capacitors

With the advent of miniature, microstrip high-frequency circuits, a whole new group of miniature components has evolved. In addition to miniature semiconductor devices, we have miniature resistors, inductors and capacitors. In the capacitor realm we have ultra-small variables and miniature electrolytics, as well as one of the smallest—and possibly the most confusing—the chip capacitor. Used for dc blocking, bypassing and fixed matching and tuning capacitors in solid state circuits, chip capacitors have become quite commonplace. Here I will describe the different types and explain where each is used.

The term *chip cap* most often refers to a multiplate ceramic cube with a metallized termination on each end. Usually, chip capacitors have no leads. The metallized termination is soldered directly to a PC board trace. Also referred to as "chip" capacitors are a group of single layer "slab" capacitors. Sometimes known as "trapezoid" or "uncased ceramic" capacitors, these devices are found in consumer electronics like UHF TV tuners. They are also popular in European high-frequency equipment.

Multiplate chip caps vary in size from roughly 0.025 × 0.025 × 0.050 inch to about 0.4 × 0.2 × 0.4 inch. The types we hams most often use are either approximately 0.05 or 0.10 inch on a side and are commonly referred to as "50-mil" or "100-mil" cubes. Capacitance values can vary from 0.1 to 100,000 pF.

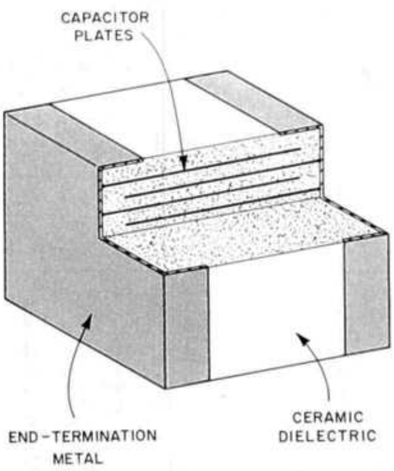


Fig 1—Cutaway view of a multilayer chip cap. The capacitor "plates" are parallel to each other and alternately connected to the end terminations. The capacitance is determined by the number and size of the plates, spacing between the plates, and by the dielectric constant of the ceramic insulating material.

Chip Capacitor Construction

The multilayer chip cap, shown in Fig 1, is simply a sandwich of metal and ceramic. The capacitor plates or "electrodes" are thin layers of metallization bonded to the ceramic when it is unfired or "green." The layers are stacked up. When the ceramic is fired, the chip becomes hard and practically hermetic. Each successive metal plate is connected to a metal termination on alternate sides of the capacitor.

The end metallization is usually made from several layers. Palladium silver is usually used to make good contact to the electrodes. Sometimes nickle is then added to act as a barrier to prevent the termination metal from dissolving after being subjected to high temperatures (soldering). On the better chip caps, the nickle is then pretinned or gold plated to make the terminations easy to solder. Some cheap chip caps are almost impossible to solder, especially when the terminations become oxidized.

The best quality microwave chip caps use porcelain ceramic as a dielectric because it is the least lossy of the ceramics. The dielectric constant of porcelain is around 6; therefore the upper capacitance limit of a 100-mil porcelain cube is around 1000 pF. Other ceramic materials are used for other types of chip caps. For instance, mixtures of magnesium titanate and calcium titanate are used to give particular temperature coefficients. One of these materials has a negative temperature coefficient and the other a positive temperature coefficient. With the right mix, it is possible to make a chip cap with no variation in capacitance with temperature (NP0). Barium titanate is used to make very high capacitance chips—up to 100,000 pF for a 100-mil cube—because of its high dielectric constant (around 500). The titanate material is quite lossy, however, and is therefore limited to low frequency applications. Porcelain is white, while the higher-dielectric-constant materials are often a grey or brownish color. Don't be fooled by cheap imitations. . .

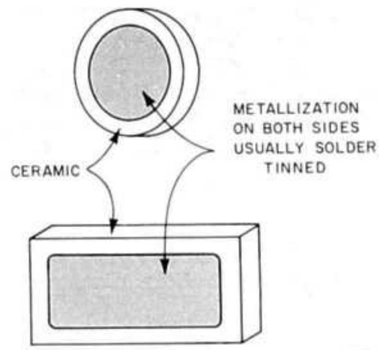


Fig 2—Single-layer chip or "slab" capacitors use a high-dielectric-constant slab of ceramic with metallization on each face.

Single-layer "slab caps" (Fig 2) are usually made from one of the high-dielectric-constant materials to get a reasonable capacitance value with a usable thickness. These capacitors are nothing but a small wafer of ceramic with the capacitor plates metallized on each face. These plates are usually solder tinned.

Performance and Specs

Chip caps are usually specified as to capacitance (measured at 1 MHz), working voltage, Q, and various mechanical and environmental properties. Other important parameters are equivalent series resistance (ESR) and series resonant frequency (SRF).

Capacitance and working voltage are pretty much self explanatory. Most good-quality chip caps in a 50-mil cube are rated at 50 V. In the 100-mil cube, working voltages range from 500 V for low-capacitance units to 50 V for a 1000-pF capacitor. Capacitance value is important if you're using a chip in a matching circuit and you're well below the series resonant frequency.

"Q" is a general term for the ratio of reactance to resistance, usually used in specifying the "quality" of ideally lossless components. The lower the loss, the higher the Q. The numbers are really only useful to us when comparing one component to another. Losses increase with both frequency and power level, so the higher the Q, the higher the frequency and power rating of a chip cap. High-quality porcelain microwave chip ca-

Table 1

Typical Series-Resonant Frequencies for Various Capacitance Values†

Capacitance (pF)	*Frequency 50-mil Cube*	*100-mil Cube*
1	9.5 GHz	7.5 GHz
5	4.2 GHz	2.9 GHz
10	3.0 GHz	2.0 GHz
50	1.4 GHz	900 MHz
100	950 MHz	650 MHz
1000	—	200 MHz

†For chip caps with porcelain dielectric only.

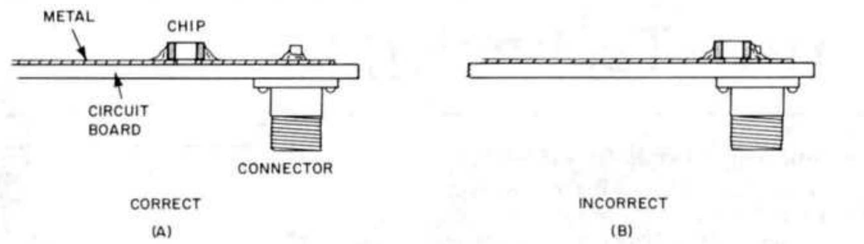


Fig 4—Correct and incorrect placement of a chip blocking capacitor attached to a connector. At B, the chip can crack when the connector is flexed. The crack can be very difficult to notice and can cause much head scratching when troubleshooting.

pacitors can be used at higher power levels than you might think. For instance, in a 50 ohm system, over 500 W CW power can be run through a 100- mil cube at 1 GHz.

Perhaps the most important parameter, especially at frequencies above 500 MHz, is the series resonant frequency (SRF). At the SRF, the inductive and capacitive reactances cancel and the chip looks essentially like a dead short. For bypassing and dc blocking applications, it is desirable to use a capacitor at or near its SRF. In fact, some high- quality microwave capacitors are specified only for frequency range for just that reason. Who cares what the value of capacitance is at 1 MHz when you're using the thing at 3 GHz! For matching and tuning applications where a particular value is called, we must make sure the chip is operating well below its series resonant frequency or else the capacitance may not be what we think it is. Remember that at frequencies above the SRF, the chip cap is actually an inductor. See Table 1.

Using Chip Caps

Most chip-cap applications call for soldering them down across a gap in microstrip circuitry. There are a few tricks you should learn to avoid frustration. The metal on the ends of the chip must be clean. Gold-plated contacts will usually accept solder without preparation. If the contacts look tarnished, they are probably palladium silver and must be burnished (brushed or carefully scraped until shiny). If they look oxidized (like old resistor leads), you must scrape off the thin layer of oxidation. Tarnished or oxidized contacts won't accept solder no matter how hot you get them.

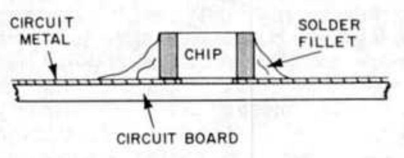


Fig 3—Solder should flow out in a smooth fillet between the circuit metal and the chip-cap end termination.

Avoid handling the chip with your fingers because finger oil can impede the flow of solder. First, tin the circuit areas where the chip is to be attached. Use tweezers to place the chip in position. Hold it in place with the tip of the tweezers while you solder one end. Use a narrow-tip soldering iron. The other end can then be soldered in the same manner, and solder can be added until each connection is nice and smooth, as shown in Fig 3. Do this quickly. Excessive heat can separate the metal termination from the ceramic or crack the chip. If everything is clean, you should have no trouble soldering quickly enough to avoid problems.

Since chip caps are made from a brittle ceramic material, care should be taken not to mount them where they can be placed under mechanical stress. A common mistake is to mount a chip cap right where a coax connector center pin attaches to a 50-ohm microstripline. This is a spot that can see considerable flexing, especially when you "hang" the box from its connectors in the back of the rack somewhere. . . See Fig 4.

Conclusions

Here are a few final hints to sum it all up:

1) Use 100-mil cubes if they will fit. They're more rugged and easier to work with.

2) In applications above 1 GHz use porcelain chips because they are much less lossy.

3) Try to get chip caps with pretinned or gold-plated end terminations.

4) For bypass applications, use a chip that is series resonant near the frequency of operation.

5) For blocking capacitors use the lowest possible value that gives proper coupling. This will make your circuit less responsive to lower-frequency signals.

6) Don't expect a chip cap to bend—it won't!

7) Use the brown 0.001 μF chips for low-frequency applications or for low-frequency bypassing on high-frequency circuits (in parallel with a high Q-chip).

8) For high-power applications use porcelain chips—they're least likely to smoke.

9) Finally, if you didn't get that pair of tweezers yet, now is the time!

See you all next month.

Bits

Topaz Semiconductor Offers A Selection of CMOS/D-MOS Analog Switches

The Topaz Semiconductor CMOS/D-MOS switches feature high-speed, low-power CMOS input logic and level translation circuitry and high speed, low capacitace lateral D-MOS switches. CMOS and lateral D-MOS circuitry are fabricated together on a single silicon chip.

Each device contains diodes to protect inputs against damage from high static voltatges or electric fields. Applications for the dual monolithic SPST CMOS/D-MOS T-configuration analog switch are RF and video switches and data acquisition. For data sheet specs and further information about the N-channel enhancement-mode lateral D-MOS FETs, P-channel enhancement-mode vertical D-MOS FETs and N-channel enhancement-mode vertical D-MOS FETs available, contact the company at 1971 N Capitol Ave, San Jose, CA 95132-3799; tel 408-942-9100. *—KA1DYZ*

VHF+ Technology

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Grounded-Grid Triode Bias Revisited

In my January 1986 column, I discussed bias circuitry for triode grounded-grid amplifiers, particularly those using higher-frequency types like the 2C39, 3CX100A5 and the 7289. As a result of that column, I received several letters detailing circuits being used by other VHF+ers. Two of the cathode bias circuits are discussed here.

The first circuit is shown in Fig 1 and was described to me in a letter from Ralph Beverly, KC4EG. The circuit has a variable current source and is similar to the one I showed, although it does not have the extra series resistance across which the bias voltage was developed in my circuit. Ralph has used it in a 2C39 grounded-grid linear amplifier on 432 MHz for many years, with good stability, 50% efficiency and no problems. Note the 1000-pF capacitor across the base-emitter junction: This really must be a good high-frequency type with short leads (its purpose being added stability of the cathode current source). Ralph notes that he does not use cutoff bias during receive operation. Instead, he has elected to draw some idling plate current at all times (ie, 30 mA during receive), with no apparent problems. With 1 kV on the plate, the resting dissipation of 30 watts may actually be beneficial for operation where plate tuning is established by a structure (cavity, line, etc) that can be detuned by a change in temperature. Keeping the receive dissipation near the transmit average dissipation *can* be one way to get around this problem. However, always keep in mind that a tube that is not cut off may, but not always, generate some noise. Experiment by providing a switched cutoff capability and see if your receiver noise level changes by only varying the grounded-grid bias from an idling current to cutoff situation.

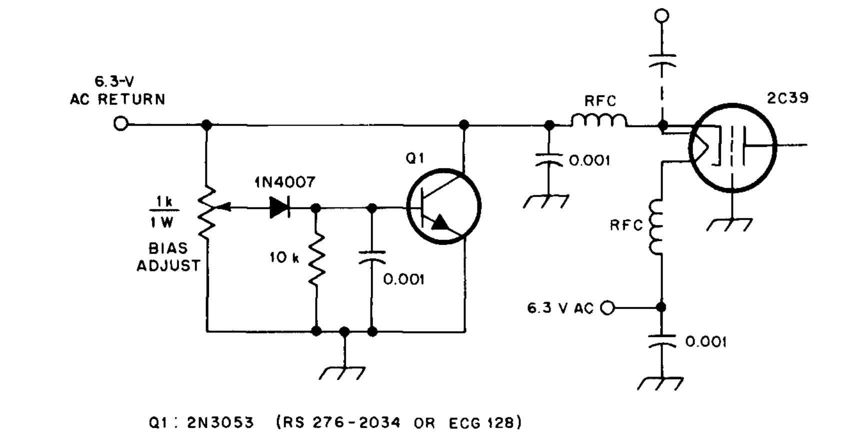

Fig 1—KC4EG's bias circuit for triode grounded-grid amplifier. See text for discussion.

Fig 2 shows a circuit provided by John Lyles, WB4PRO. It represents a commercial VHF class-C grounded-grid amplifier using a 3CX1500A7/8877 (50/144/220 MHz ops take note). The series resistance and the Darlington-connected transistors in this circuit handle the higher cathode current of the tube. Since this bias regulator is normally set to keep the tube cut off, and allow conduction only on the positive peaks of the driving signal, it cannot be used, as is, for linear operation. However, it illustrates another variation on the basic bias regulator and gives a wider latitude of circuitry to choose from.

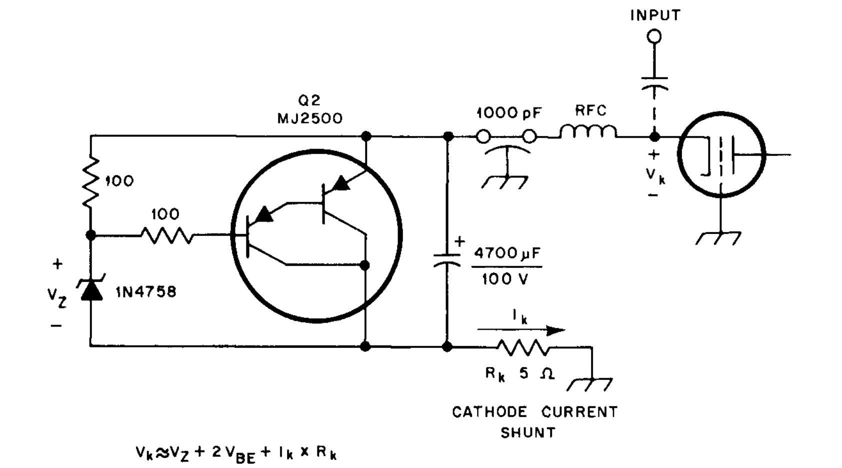

Fig 2—This circuit represents a commercial VHF class-C grounded-grid amplifier using a 3CX1500A7/8877 tube.

TWT Information Needed

One of the truly fantastic special microwave tubes is the Traveling Wave Tube (TWT). A small quantity of type 564HD tubes (Hughes Electrodynamics) have been made available to some of the Northeast microwave fanatics, but data is incomplete. I would like to discuss the operation of these tubes, if several can be made to operate (and provide a good learning experience to us younger, solid-state era VHF+ers). To that end, does anyone have additional information on the 564HD? (Help get more 2300+ MHz stations on the air.) The tubes have SMA input/output connectors and appear to be 10-watt instrumentation amplifier devices for 2 to 4 GHz. That's right, these wideband amplifiers will cover both 2304 MHz and 3456 MHz. With a gain of about 30+ dB (for a typical TWT), an input signal of no more than 10 mW (+10 dBm) will drive the amplifier to full output. All this in a package measuring 10 × 2 × 2 inches! All the TWT usually needs are the proper power supplies and power connections. That is where everyone's problems occur: finding out which lead or pin goes to which electrode and gets which voltage! These 564HDs have five flying leads and a dataplate with voltages (Ef = 6.3, Ek = −1475, Ea = 100 and Eb = −500) and a current rating (IK = 79 mA). An ohmmeter check shows low resistance between the brown and yellow leads, so these are the filament; but the cathode is usually connected to one side of the filament, and this is unknown without more information (you generally do not want the additional cathode current flowing through the filament). Several VHF+ers with TWT experience were questioned, but would not guess at the connections of the additional yellow, green and red leads, or which electrodes to measure Ek, Ea and Eb between. One local contester has a 2- to 4-GHz TWT in operation, but it is made by a different manufacturer, uses different voltages and may have a different electrode configuration. Any specific information on tube or Hughes 2- to 4-GHz rack amplifiers would be greatly appreciated.