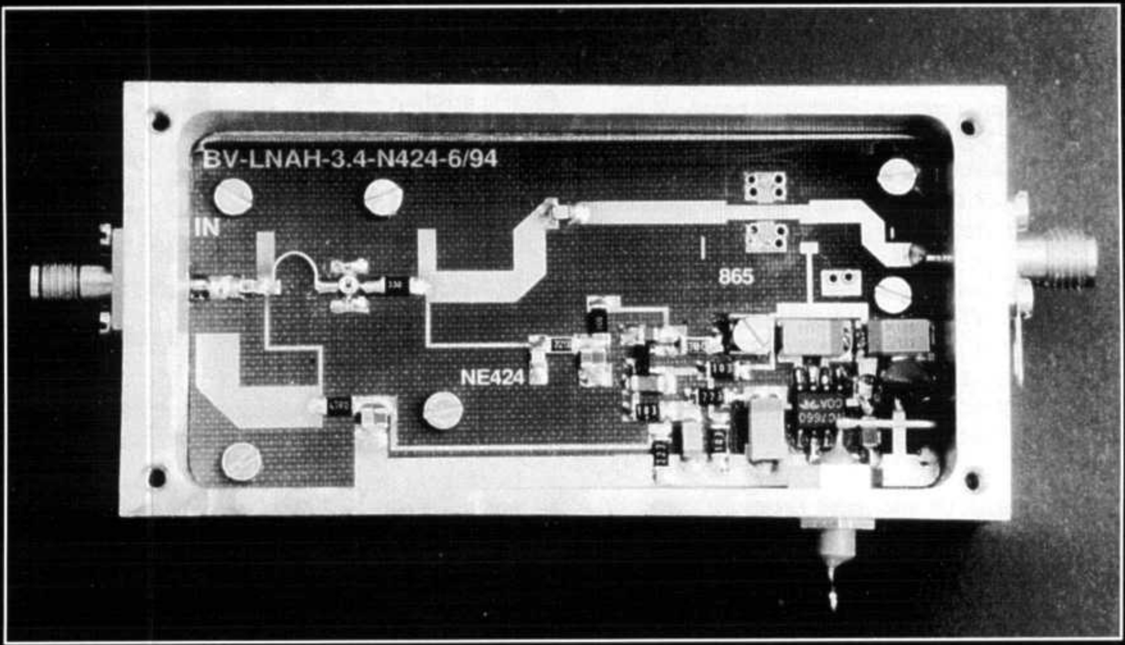
QEX

$1.75

ARRL Experimenter's Exchange

December 1995



A 9-cm Preamp that *Performs*

QEX: The ARRL
Experimenter's Exchange
American Radio Relay League
225 Main Street
Newington, CT USA 06111

QEX (ISSN: 0886-8093 USPS 011-424) is published monthly by the American Radio Relay League, Newington, CT USA.

Second-class postage paid at Hartford, Connecticut and additional mailing offices.

David Sumner, K1ZZ
Publisher

Jon Bloom, KE3Z
Editor

Lori Weinberg
Assistant Editor

Harold Price, NK6K
Zack Lau, KH6CP
Contributing Editors

Production Department

Mark J. Wilson, AA2Z
Publications Manager

Michelle Bloom, WB1ENT
Production Supervisor

Sue Fagan
Graphic Design Supervisor

Joseph Costa
Technical Illustrator

Joe Shea
Production Assistant

Advertising Information Contact:

Brad Thomas, KC1EX, *Advertising Manager*
American Radio Relay League
860-667-2494 direct
860-594-0200 ARRL
860-594-0259 fax

Circulation Department

Debra Jahnke, *Manager*
Kathy Fay, N1GZO, *Deputy Manager*
Cathy Stepina, *QEX Circulation*

Offices

225 Main St, Newington, CT 06111-1494 USA
Telephone: 860-594-0200
Telex: 650215-5052 MCI
FAX: 860-594-0259 (24 hour direct line)
Electronic Mail: MCIMAILID: 215-5052
Internet:qex@arrl.org

Subscription rate for 12 issues:

In the US: ARRL Member $12, nonmember $24;

US, Canada and Mexico by First Class Mail: ARRL Member $25, nonmember $37;

Elsewhere by Surface Mail (4-8 week delivery): ARRL Member $20, nonmember $32;

Elsewhere by Airmail: ARRL Member $48, nonmember $60.

QEX subscription orders, changes of address, and reports of missing or damaged copies may be marked: *QEX* Circulation. Postmaster: Form 3579 requested. Send change of address to: American Radio Relay League, 225 Main St, Newington, CT 06111-1494.

Members are asked to include their membership control number or a label from their *QST* wrapper when applying.

About the Cover

This DJ9BV preamp delivers top-notch performance at 9 cm.

ISSUE NO. **166**

Features

December 1995 QEX Advertising Index

American Radio Relay League: 29, 30, 31, Cov IV
Comer Communications Inc: 31
Communications Specialists Inc: 31
Down East Microwave, Inc: 32
PacComm: Cov II, Cov III
PC Electronics: 32
Sescom, Inc: 32
Tucson Amateur Packet Radio Corp: 31
Z Domain Technologies, Inc: 31

THE AMERICAN RADIO RELAY LEAGUE

The American Radio Relay League, Inc, is a noncommercial association of radio amateurs, organized for the promotion of interests 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 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 1986. 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.

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.

Membership inquiries and general correspondence should be addressed to the administrative headquarters at 225 Main Street, Newington, CT 06111 USA.

Telephone: 860-594-0200
Telex: 650215-5052 MCI
MCIMAIL (electronic mail system) ID: 215-5052
FAX: 860-594-0259 (24-hour direct line)

Officers

President: RODNEY STAFFORD, KB6ZV
5155 Shadow Estates, San Jose, CA 95135

Executive Vice President: DAVID SUMNER, K1ZZ

Purpose 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 06111 USA. 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 doubled spaced. Please use the standard ARRL abbreviations found in recent editions of *The ARRL Handbook*. 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*.

Empirically Speaking

Electronic *QEX*?

One of the more interesting developments in this, the last decade of the 20th century, is the rapid growth in ways of producing and delivering electronic publications. We're not unaware of these trends; we've been thinking for some time about ways of delivering *QEX* more efficiently using electronic means. What we'd like to know now is: what do *you* think?

What we have in mind is delivering *QEX* via the World Wide Web, from the ARRL's *ARRLWeb* server. This isn't a commitment to do that—we're still in the thinking stage. And the particulars of *how* we do it, *if* we do it, remain undetermined. But we have some ideas.

What seems most promising at the moment is delivery of *QEX* in the form of Adobe, Inc, *Portable Document Format* (PDF) files. These files can be viewed using Adobe's *Acrobat* viewer, which is freely available for downloading from www.adobe.com in DOS, Windows, Macintosh and unix versions. The advantage of PDF is that the magazine page image you see is almost exactly what appears on the printed page of the physical magazine. The main difference is caused by the limited resolution of your display or printer. (Unless, of course, you happen to have a high-resolution phototypesetter handy!)

To see an example of the possibilities, you might take a look at URL http://www.arrl.org/ard/ardarts.html, which contains links to the PDF versions of 1995's "Exploring RF" columns from *QST*. (You'll need *Acrobat* to view the files; the same URL will tell you how to get it.)

QEX in PDF is not likely to be particularly small. The 2-3 page "Exploring RF" columns range in size from about 50 to 200 kbytes in size. A 32-page issue of *QEX* would, therefore, be a pretty large file. Is that a problem? Would it be best to break such a file into chunks, such as one article per file? (Recently, Adobe has announced tools that allow PDF files to be served up a page at a time. This looks interesting, but is currently limited to users using *Windows 95* and *Windows NT* versions of *Netscape*. It's not quite yet ready for "prime time.")

Or is there a better way to deliver *QEX* electronically? If it's worth doing at all, that is. We should note that we are not talking about making *QEX* available for free download. We can't afford to do that, as the cost of printing and mailing *QEX* is only part of the overall cost of producing it. So, you would still have to subscribe, although probably at a discount compared to getting it by mail. Likely you would have to supply a password to download the current issue.

We're interested in your opinions on this matter. Is it worth doing? Email us at qex@arrl.org and let us know. How *QEX* readers respond is likely to have a large impact on how—and if—*QEX* is delivered electronically.

This Month in *QEX*

Think the commercial manufacturers of amateur gear have a corner on making transceivers with direct digital synthesis, microprocessor control and good performance? Not so, as Tim Ahrens, WA5VQK, and Rand Gray, W1GXN, have shown in, "A Microprocessor Controlled Multiband Transceiver."

Cheap microwave dishes! That's what those new direct-satellite TV systems have, and they look perfect for 10-GHz work, too. But how to illuminate them? In "More on Parabolic Dish Antennas," Paul Wade, N1BWT, shows how to do it. He also has some useful tips on other feed systems and on using sun noise for system measurements.

The 9-cm band has lots of promise for amateurs, but you'll need a good preamp, such as the "PHEMT Preamp for 9 cm," by Rainer Bertelsmeier, DJ9BV.

Take a look at our annual index, appearing in this issue. It *has* been an exciting year! *—KE3Z, email: jbloom@arrl.org*

A Microprocessor-Controlled Multiband Transceiver

Who says building your own full-featured transceiver is a thing of the past?

By Tim Ahrens, WA5VQK, and Rand Gray, W1GXN

Since our early novice days we have always wanted to build a really substantial project but seemed to fall a bit short most every time, with super-regens that "kinda" worked and false starts on multiband rigs through the years. (Most of the plans were from *QST* and the *Handbook*, but either funds ran out or enthusiasm waned before the project was complete.) It seems that things were more complicated back then, but perhaps it was only a matter of perspective. Now, once again on the upsurge of ham radio interest, we wanted to build that elusive multiband rig. Sure, all it takes is a bit of plastic money to make a radio appear in the shack, but since both of us are more tinkerers/builders than operators, there wouldn't be much thrill in doing it that way.

How do you design a multiband SSB rig—and do a good enough design that you would be satisfied with the results? Since Heath is gone, it seems that nobody makes even the basics of a buildable multiband radio, much less one with a fancy front panel with features we have all come to expect.

A couple of years ago, the NorCAL QRP Club started sending out their quarterly journal *QRPp*, which is a really nice piece of literature. In one of the recent issues, there were no less than three SSB rigs highlighted! It seems that there are a lot of kit and home-brew projects available from overseas sources, especially the UK. The one rig that caught my eye was from Hands Electronics (UK) and sold here in the states by Kanga USA.

The Rig

This rig was a six-band SSB/CW rig with a power output of about 10-20 W, depending on the band. It could be bought as a partial kit, buying only those tuned circuits or boards required for the type of radio that you wanted, and it had a lot of home-brew customization options that were left to the builder. You didn't need a rack full of test equipment to build the box either. It was definitely not a Heathkit, but that wasn't necessary. Hand holding

Tim Ahrens, WA5VQK
14824 Bear Creek Pass
Austin, TX 78737
email: tahrens@devmail.sps.mot.com

Rand Gray, W1GXN
5807 Abilene Tr
Austin, TX 78749
email: rtnm10@email.sps.mot.com

wasn't required, as we both can read schematics, solder, build and analyze things. The total price was about what you could pick up a used "Yaecomwood" rig for at a hamfest, but the idea here was to build it, not buy it!

Okay, we had the RF guts, but the box needed a microcomputer to be a "real" radio! Question: Can you really call something home-brew if all you do is build it from a kit? Answer: *of course*! Tim had done a couple of different HF rig front panels in the past, and Rand had written bunches of code, so what was another computer project? After a couple of chats with Bill Kelsey, N8ET, of Kanga USA, and Sheldon Hands (Hands Electronics) in the UK, we decided that the project would be both to upgrade the existing RF boards, to add the newer ham bands to the original 6-band design and provide more functions and better performance. We also added a microcontroller to handle board and mode switching, frequency control and display and transmit/receive control. In addition, we use one of the new direct digital synthesis (DDS) chips for frequency control. This DDS decision was made both for simplicity of design and for adaptability to other frequencies—without a major VFO redesign. While Rand was cranking on the software, Tim pursued the hardware and PC-board design. This article describes in detail the operation of the front panel, but we'll also give a brief overview of the RF modules. The Hands Electronics RF modules are available from Kanga USA and the front panel is available from the authors.[1,2] For sales abroad, both the RF modules and the front panel board are available from Hands Electronics in the UK.

Here are the operational specifications of the rig:

- 10-band operation (all HF ham bands)
- SSB and CW modes at 10-20 W output
- LCD for frequency and information display (2 × 16 characters)
- Full break in (the only relays are in the low-pass-filter board)
- Rotary shaft encoder for tuning
- RIT
- Split TX / RX operation
- Memories (for both frequency and mode)
- Direct frequency entry via a 4 × 4 keypad
- "Digital" S-meter
- Variable reference
- RF preamp
- SWR/power meter
- Audio derived AGC with manual gain override
- "Hear through" CW sidetone
- SSB/CW audio filters
- EEPROM storage for memories—no battery to replace, ever
- Built in keyer with dot and dash memory
- Optional outboard 9-MHz filter (CW or SSB)

What follows is a brief description of the RF boards in the rig. Fig 1 shows the block diagram of the complete multiband transceiver.

IF Board

The IF board is based on standard 9-MHz components. It comes supplied with a 2.3-kHz crystal filter that does quite well in an SSB environment. The addition of the audio filtering on the AGC board complements this filter and makes for some very nice sounding audio. Most any 9-MHz filter could be used on the board, including those from KVG and the old Dentron single-banders filters. This filter is diode switched for inputs and outputs to the RF and SYNTH boards. Optionally, an additional CW filter may be mounted outboard and selected from the front panel.

In receive, the 9-MHz IF signal passes through the crystal filter, then through two MC1350 IF amps in cascade. The output from the AGC board and RF gain pot feed into these IF amps to provide appropriate AGC action. The 9-MHz IF signal then enters an NE602A, configured as a product detector, which gets its other input from the switchable carrier oscillator (9001.5 or 8998.5 kHz). The output of the NE602A then goes into an LF351 audio predriver, followed by some further audio passband filtering. The resulting audio goes through the W7EL audio mute switch and into a TDA2003 audio amplifier. In early versions of the IF board, the audio sounded good at low listening levels but didn't have enough "uumph" for that fill-the-gym type of audio. This revised board really sounds good!

During SSB transmit, the microphone audio is capacitively fed into a Plessey SL6270 VOGAD (Voice Operated Gain Adjusting Device—a mic preamp with AGC) on the IF board, which provides about 60 dB worth of AGC range. The audio from this device is fed into an SL1640 active double-balanced mixer that produces a double-sideband signal. The selectable carrier oscillator is also fed into the SL1640. This DSB signal is fed into a J310 FET that amplifies the signal and matches the impedance to the crystal filter. The output of the filter is 9-MHz SSB that is used to drive the transmit mixer board. If you feel you need additional control of your mic audio, you can add a pot to the board for variable control. In CW transmit, the SSB audio stages and mixers are disabled and a third 9-MHz oscillator is keyed, supplying the synthesizer board with a CW signal. This oscillator includes a variable capacitor to provide the capability of shifting the beat note. The IF stages, AF amp and mixer are kept active during CW transmission to allow "listen-through" audio. Several unsolicited "terrific audio" comments have been received while using this rig.

Receive Mixer Board

The RMX10 10-band receiver mixer board functions provides an RF preamp, band-pass filters and the receive mixer. The RF preamp is selectable: if you don't need it, press the appropriate button on the keypad to turn it off. The preamp is a low-gain, high-dynamic-range receiver preamp. It uses four parallel J310 FETS run in a grounded-gate configuration to give both a low noise figure and good strong-signal handling capabilities. The receive signal first goes through the low-pass filter, then through the solid-state T/R switch. All of the switching functions in the rig use BA479/379 type PIN diodes to do the signal switching (except for the T/R switch, which uses 1N4007s). If you are an RF purist, you may opt to replace these with one of the more expensive types of PIN diodes available. There have been several articles discussing the pros and cons of various diodes in recent issues of *QST*. The signal next goes into a series of band-pass filters, again diode switched. The board has provisions for filters for ten bands. You may order them all at once or build only the bands you are interested in. To lower your stress level, most of the inductors used are standard Toko shielded types. (Some say that there are people who really like to wind lots and lots of toroids by hand, but don't believe it!) The signal then is fed into an SL6440 high-level mixer. This mixer is *not* your typical NE602 variety. The spec sheet says that, "when biased for a supply current of 50 mA, the SL6440 offers a 3rd-order

---

[1] Notes appear on page 13.

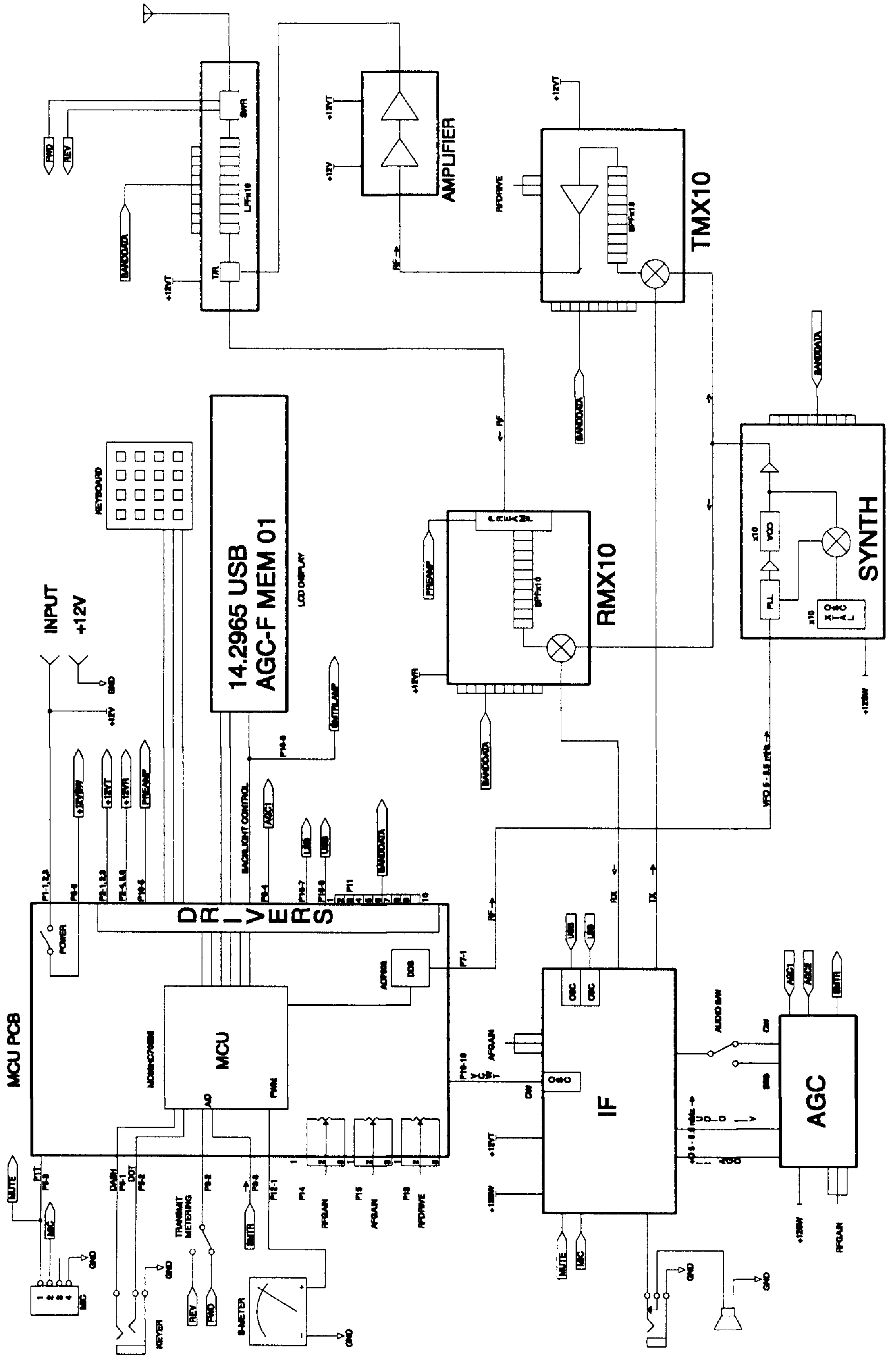


Fig 1—Block diagram of the multiband transciever

intermodulation intercept point of typically +30 dBm." The other input to the SL6440 comes from the synthesizer board. The output of the mixer is fed to the 9-MHz input of the IF board.

Transmit Mixer Board

The TMX10 transmit mixer board consists of the mixer, band-pass filters and the output amplifier. The mixer is another SL6440 high-level mixer. The 9-MHz signal (SSB or CW) from the IF board is mixed with the output of the synthesizer board (essentially the HFO signal), and the output is fed into one of 10 band-pass filters. These filters are also switched via PIN diodes that are controlled by the MCU/DDS board. The output of the selected filter drives a 2N3866 amplifier whose output in turn drives the power amplifier board directly. The 2N3866 provides enough output to drive the power amplifier to 20 W on 80 meters, reducing to 10 W on 10 meters.

AGC and Audio Filter Board

The AGC board uses an audio-derived AGC voltage and works quite well. The audio input to the board comes from the IF board, and the selectable output (SSB or CW) is fed back into the volume control pot, which in turn feeds the audio output stage of the IF board. The CW output has a slightly higher gain than the wider SSB position and actually enhances the signal by this slight increase in volume. The AGC generation part of the circuit has two separate inputs from the MCU/DDS board that allows several time constants to be used. If you desire, you can add some additional audio filtering (such as peaking or notch controls) at the output of this board.

Synthesizer Board

The synthesizer board is of the 'summing loop' variety. Designed by GM4ZNX and G3ROO, it has been published in both *SPRAT* and *Radio Communication*.

In a summing-loop synthesizer, a mixer takes the place of the divider, and the VFO input actually serves as a variable reference. The loop filter drives one of ten selectable VCOs, and this VCO drives both the outputs of the board and one side of a NE602 mixer. The other side of the mixer is fed with one of ten crystal oscillators, depending on the band that is selected. (An excellent detailed description of this technique is found in the *Handbook*.) Although the system is a less than stellar performer in the phase-noise arena, it is simple to build and extremely easy to align. That ease of alignment is one of the goals of this transceiver. At some point in the future, a PLL system may take the place of the crystal oscillator bank.

Power Amplifier Board

The power amplifier board is a three-stage wideband linear amplifier that has been designed for SSB and CW service. It has a frequency range of 1.8 to 30 MHz and a gain of about 40 dB. This makes it a perfect choice to be driven by the TMX10 board. Actually, if you only need an amplifier for your pet project and don't want to build up the remainder of the boards, this amplifier will save you a lot of headaches!

The first stage is a 2N3866 running in class A. Negative feedback ensures a consistent gain at frequencies from 1.8 to 30 MHz. Both the second and third stage are of the push-pull variety and have similar feedback components that help to make the gain constant. The driver and final stages have separate bias current controls and measurement points. These bias generators are enabled by the switched +12 V (transmit). Temperature compensation for each stage is provided by placing one of the bias-generator transistors against the body of the power transistor with silicon grease. As the actual amplifier stages are cut off when the bias voltage is zero (as in receive), the collectors of both stages may be connected directly to the +12-V line.

Low-Pass Filter, TX/RX switch and SWR Bridge

The low-pass filter board contains six cascaded low-pass filter sets. Depending on the band selected, small relays switch in the proper number of filters. As the 14, 21, and 30-MHz filters are also suitable for the 10, 18, and 24-MHz bands, isolation diodes are provided in the switch lines. The T/R switch uses 1N4007 diodes. This board also has a forward/reflected power meter which feeds the MCU/DDS board.

The Front-Panel Board

The front-panel board (Figs 2 through 5) is the all-new part of this project, and it's really the part that turns this from a "specialty" unit into a rig that could comfortably sit in most any shack. This board contains all of the digital circuitry: the microprocessor, direct digital synthesizer, bandswitch control, S-meter, serial EEPROM, liquid-crystal-display module and various front-panel controls, including the keypad and controls for RIT and keyer speed.

The Microcontroller Unit (MCU)

The microcontroller selected for this application is the Motorola M68HC705B5, U2, which is a one-time-programmable (OTP) low-power, high-speed CMOS unit. We selected this MCU for its low cost and appropriate set of features for this application, including: field-programmability; a simple, easy-to-program microprocessor core; multiple analog-to-digital (A/D) converters; pulse-width modulator (PWM) outputs; a simple serial interface and a timer.

The timing for the MCU and DDS is provided by a single 40-MHz hybrid oscillator, U4. The output of this oscillator-in-a-can goes straight to the DDS and also to a 74HC390, U3, which divides the 40-MHz signal by 10 to provide a 4-MHz clock for the microcontroller. The reference for the DDS gives a ratio of 7.3 (40 MHz / 5.5 MHz) between the clock and the highest frequency generated by the DDS. This provides an adequate number of samples so that we get a decent sine wave with simple filtering. Earlier experimentation using a clock of 16 MHz (a ratio of 2.9) yielded a VFO output waveform that left much to be desired.

The DDS Chip

The DDS function is provided by an Analog Devices AD7008, which includes a phase accumulator and a D/A converter in a single device. We chose the AD7008 because it provides the DDS function in a single 44-pin plastic-leaded chip carrier (PLCC) and is very easy to program. The device has two frequency control registers, allowing for easy shifting between two output frequencies, which we take advantage of for RIT and split operation. The reconstructed sine wave that comes out of the DDS is filtered by a five-pole low-pass filter.

The MCU Data Bus

As is the case with most single-chip MCUs, there is no external data bus on the 68HC705B5. However, we need a parallel data bus—for the LCD module and the DDS chip—and some means of getting data into the band registers and the serial electrically erasable programmable read-only memory (EEPROM). This is done by

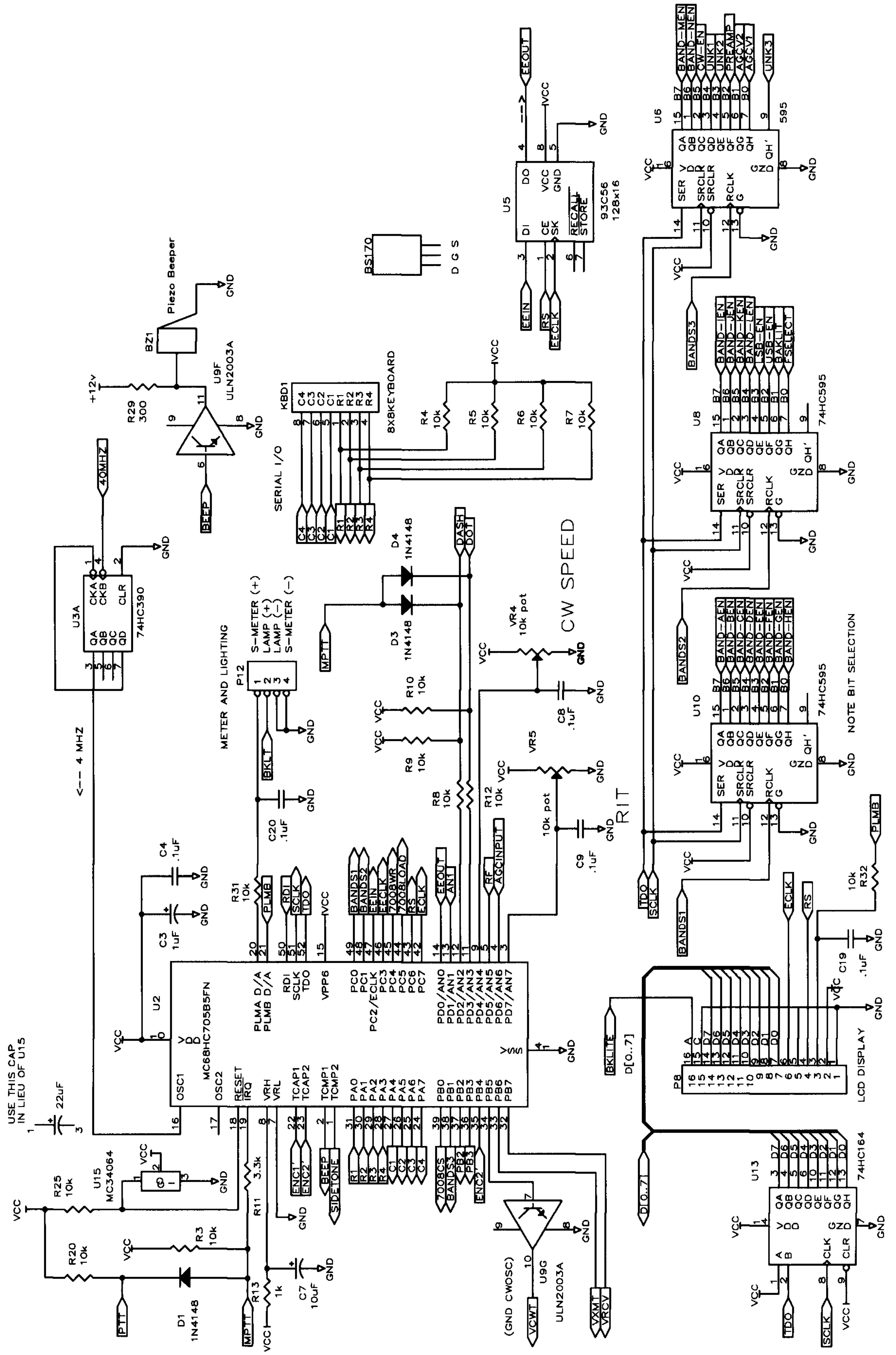


Fig 2—Schematic diagram of the MCU circuitry on the front-panel board.

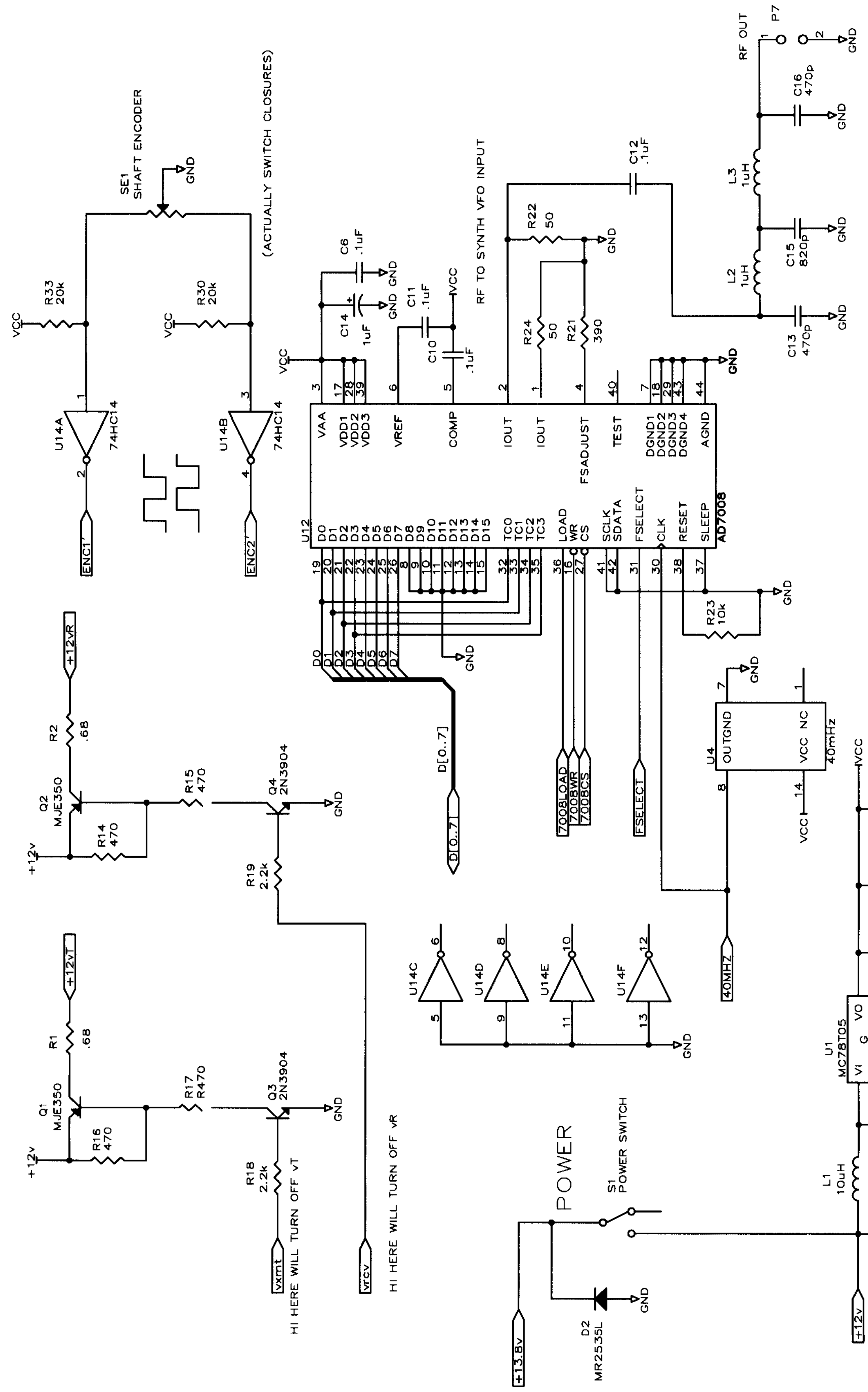


Fig 3—Schematic diagram of the DDS circuitry on the front-panel board.

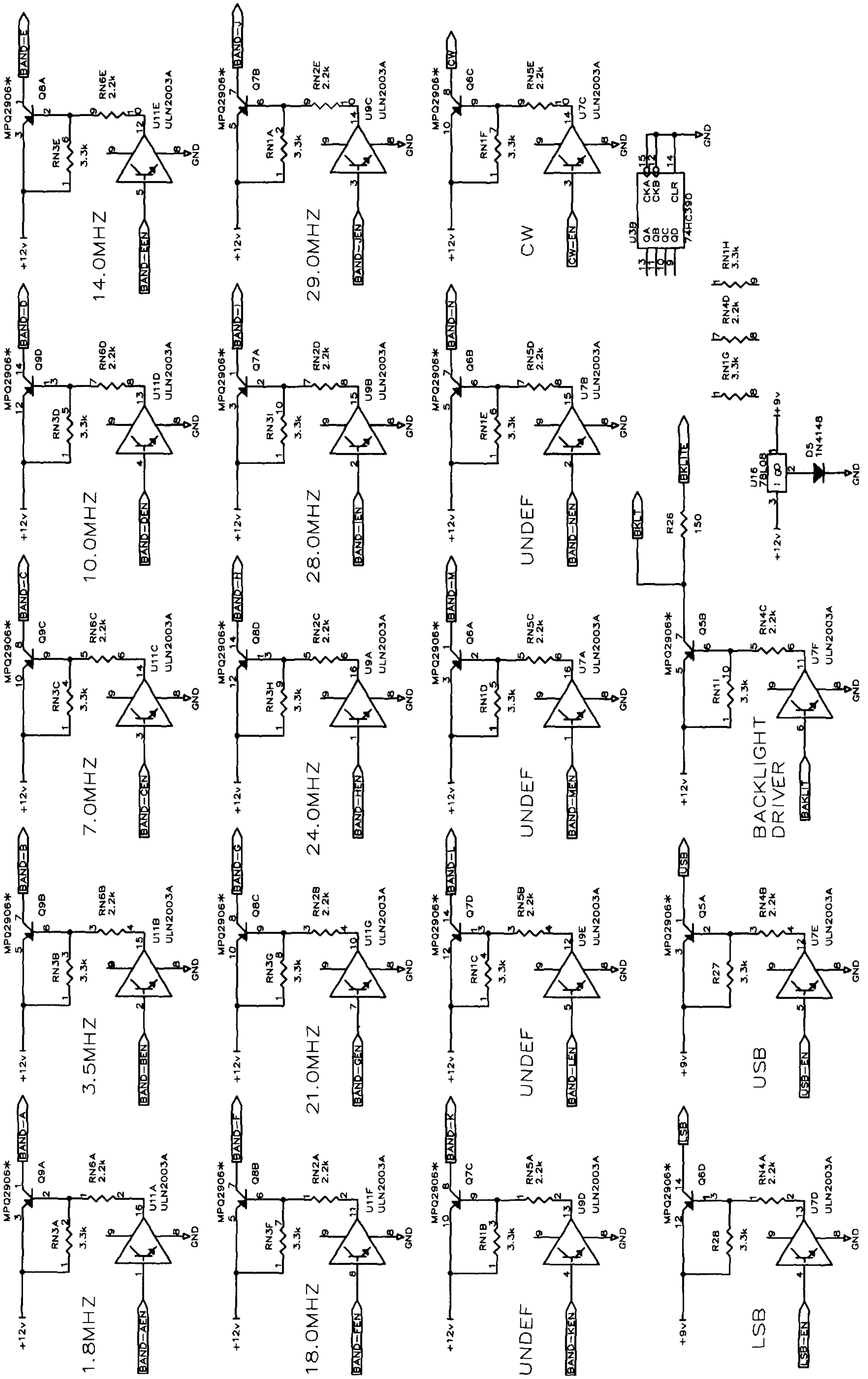


Fig 4—Schematic diagram of the driver circuitry on the front-panel board.

making use of the simple serial interface of the MCU. In order to provide parallel data to the LCD and DDS, we use a 74HC164 serially loadable shift register. This causes a little bit of additional complication when programming the parallel data devices. We do this with a simple function called *sendchar*. Fig 6 shows a flow chart of *sendchar*.

DDS Control

The DDS can be controlled by either the keypad or the digital shaft encoder. The shaft encoder, SE1, has three pins: ENC1, ENC2, and ground. ENC1 is connected to the TCAP1 (timer input capture 1) pin of the MCU. ENC2 is connected to MCU I/O port B4, which is used simply to sample an input level of one or zero. The TCAP1 pin is programmed to interrupt the MCU whenever a negative edge (high-to-low transition) is detected. By examining the input level of ENC2, it is possible to sense the direction in which the shaft is turning (clockwise or counter-clockwise). Each edge detected on ENC1 causes the frequency to increment or decrement, depending on the level detected on ENC2. Fig 7 shows a flow chart of the interrupt service routine for the TCAP1 pin and demonstrates how the shaft encoder interface works.

The DDS frequency is controlled by either one of two phase accumulator frequency registers. The appropriate register is controlled by the FSELECT pin, which is connected to a spare bit of band register 2. Each frequency register is 32 bits in length, and the frequency output of the DDS is given by the equation:

$$f_{out} = \frac{f_{reg}}{2^{32}} f_{osc}$$

where f_{reg} is the 32-bit value in the frequency register and f_{osc}=40 MHz, the frequency of the CLK input to the DDS.

Keeping track of the frequency in the MCU is accomplished by using a logical frequency representation of five binary-coded-decimal (BCD) bytes. These are converted to a physical 32-bit binary value that is written to the proper DDS frequency register. In the radio, the local oscillator reference tunes "backwards," and thus the logical-to-physical conversion must take care of this as well.

When tuning with the shaft encoder, the DDS frequency is updated incrementally; that is, it is incremented or decremented by a programmable step. The step size may be programmed to be 10 Hz, 100 Hz, 1 kHz and so on, thereby setting the tuning resolution. The current frequency increases or decreases by the current step size for each shaft encoder interrupt. The reason for a programmable frequency step size is to allow the individual user to choose the tuning resolution for a given shaft encoder. With the encoder used in our rig, there are 50 interrupts per revolution of the shaft. Thus, for 100-Hz steps, a single revolution of the tuning knob results in a frequency change of 5 kHz.

When entering the frequency from the keypad, the frequency resolution is always 10 Hz, even though the user does not have to enter it with that much precision.

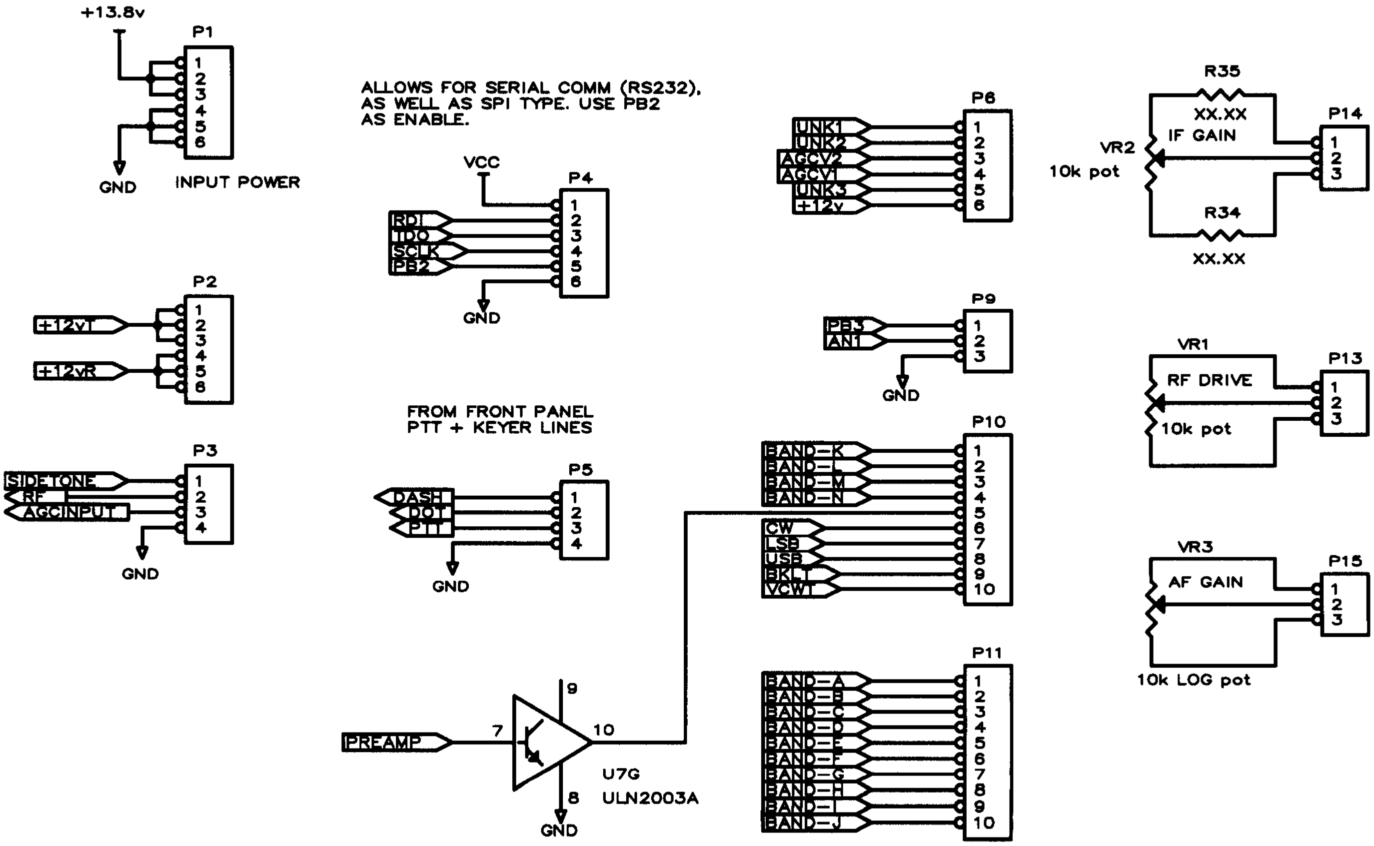


Fig 5—Front-panel board connections.

The Keypad

The 16-key keypad is a standard 4 × 4 matrix that is connected directly to the MCU. Four outputs from the MCU I/O ports are used as strobes connected to the keypad columns, and four inputs from the MCU I/O ports are used as input sense lines connected to the keypad rows. Fig 8 shows the layout of the keypad and its connections to the MCU I/O ports. The lower right-hand corner key selects the "second function" of each key. The second function of each key is listed below the primary function for the key. For example, to select LSB mode, you would press the "2nd" key, then the "1" key.

The keypad lets the user: directly enter frequencies, store and recall memory channels, select the desired band, select the operating mode (LSB, USB, CW or AM, but this version of the radio does not support AM operation), select fast or slow AGC, toggle the display backlight on and off, toggle the preamp on and off, turn the keypad beep on and off, select keying by paddle or straight key, set up and calibrate the radio, turn RIT on and off, lock or unlock the shaft encoder, select the external filter (if any), select fast or slow tuning rates, set the tune mode, and set up split-mode frequencies.

The MCU both decodes and debounces the keypad. The four sense lines that are connected to the rows of the keypad are all pulled up by resistors. To detect if a key is pressed, all of the column strobes are set to 0 and the levels of the sense lines are checked. If any are at a 0 level, a key in that row has been pressed. The MCU then writes only one 0 at a time to each of the column strobes to isolate the column of the pressed key. The column and row intersection identifies the pressed key. Fig 9 shows a flow chart of the keypad debouncer/decoder. An additional function detects when the user releases the depressed key.

The parsing of the keypad is done with a software finite state machine (FSM). Parsing is determining what to do with each keystroke. Each entry puts the state machine into a specific state, and the threading of the state machine reveals the key sequence to the software. The state machine is implemented with a series of tables.

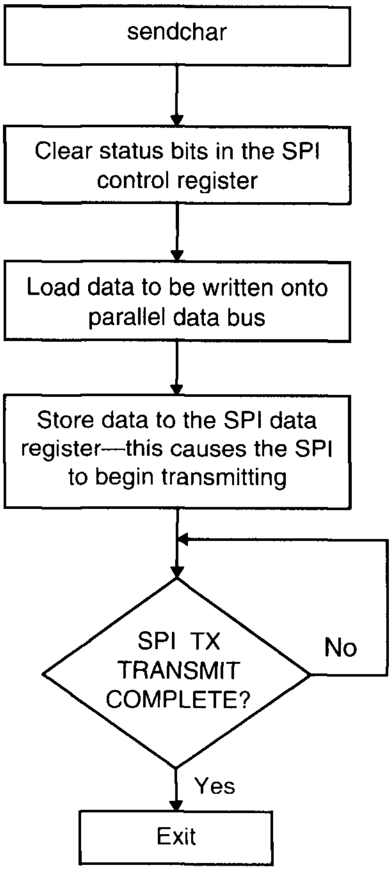


Fig 6—Flow chart of the *sendchar* routine, used to load the parallel data bus.

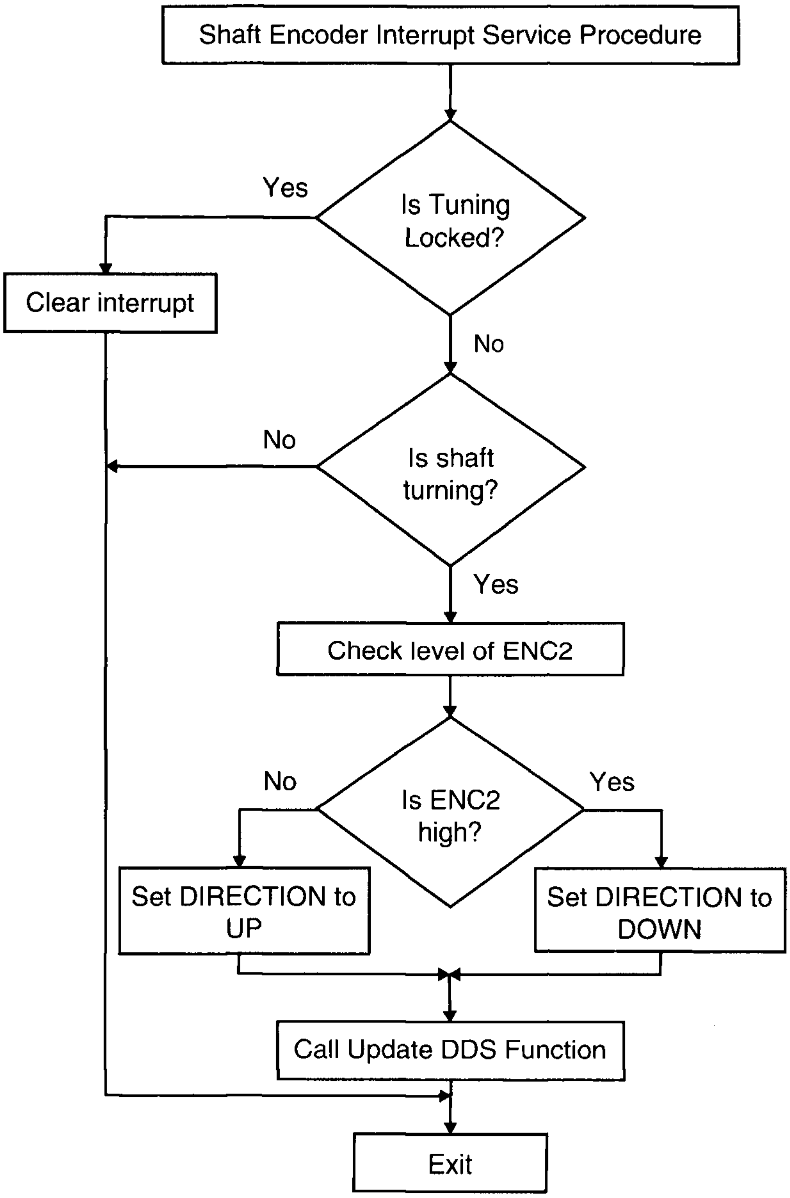


Fig 7—Flow chart of the shaft encoder interrupt-service routine.

For each FSM transition, there is a possibility to do some additional processing for each state.

Keyer Speed and RIT Controls

The RIT and keyer-speed controls are simply potentiometers that provide a voltage from 0 to 5 V to the MCU A/D inputs. The MCU program can read each of these inputs as a binary number from 00000000 to 11111111 (00 to FF_{16}). The range is divided in half, such that when RIT is enabled, a value of 80_{16} corresponds to zero offset, 00_{16} corresponds to the largest negative offset, and FF_{16} corresponds to the largest positive offset. For RIT, the offset integer then adds or subtracts a fixed amount from the logical frequency. This is then converted to a physical frequency and written into the alternate frequency register of the DDS IC.

Keyer Inputs

The function of the keyer inputs is controlled by the MCU. In the straight-key mode, the dot input is used as a single input from a straight key (or the output of your favorite keyer). In the paddle mode, both dot and dash inputs should be connected directly to your paddle.

Digital S-Meter

Notice that the S-meter is driven directly from the MCU and not from the AGC stage. How come? Well, how many rigs have you seen where an S9 signal is really the standard 50 µV? Few, we bet. That's because it is really difficult to make a radio that has the same amount of gain through all of its band-pass filters; some are more lossy than others. Here is how the S-meter works in this rig: The AGC voltage comes into the MCU through the 8-bit A/D converter. Through a small lookup table in the EPROM, this signal is converted to a known value and sent through the MCU's D/A converter, which drives the S-meter. The calibration procedure requires a signal generator that has a known 50-µV output for all bands that you want calibrated. If you hold the "1" key on power-up, you will enter the calibration routine. The RIT pot is used to zero in on S9. This digitized S-meter is active in the receive mode, and the SWR/power meter is active in transmit. The meter is driven from the MCU PWM output, which is filtered by a simple R-C integrator to average out the PWM square-wave signal and provide a variable dc level.

Other A/D converter inputs include the keyer speed pot, RIT pot and RF input (output of the SWR/power meter). Although an additional shaft encoder could have been used for the RIT input, a potentiometer works

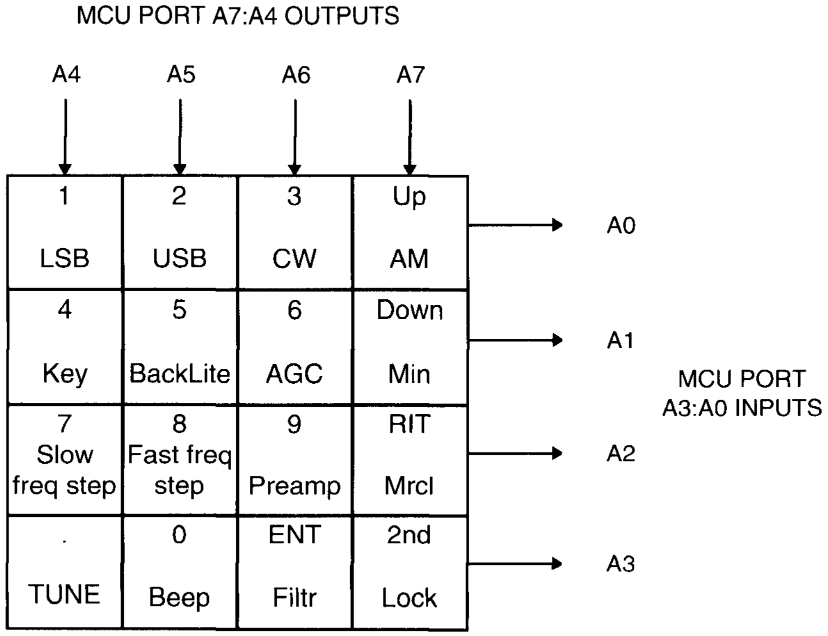


Fig 8—Keypad functions and connections.

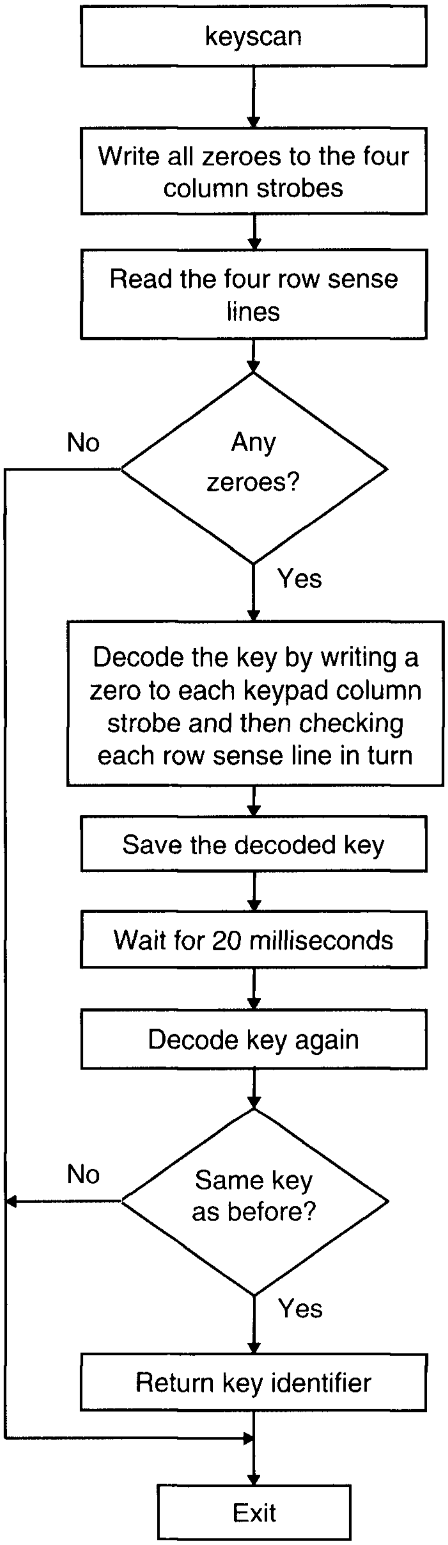


Fig 9—Flow chart of *keyscan*, the keyboard decoding and debouncing routine.

quite well and is considerably less expensive.

Variable Reference

With the new digital rigs, how do you know that you are really on frequency? If they are using synthesizers with a common reference frequency, no problem. However, if there are multiple crystal oscillators (as in this design), you may run into the problem of an oscillator that is not quite where the microcontroller thinks it is. Sure, you can periodically check the frequency with a frequency counter, but that requires that you get into the radio and adjust things. The way this system works is that normally—without any special initialization—the MCU thinks that the oscillators are where they should be. However, if you want to be *exactly* on frequency, we have provided a way. Upon power-up, hold the "3" button on the keypad. This puts you into a calibration mode. The LCD will prompt you to apply a specific frequency (one for each band), and allow you to adjust the main tuning for zero beat. The difference value that the computer calculates (how much the other oscillators are off frequency) will then be used as an offset that is applied in generating the VFO signal. It will be stored in the EEPROM, so the frequency will be correct the next time you turn on the radio. To compensate for aging crystals, you may do this calibration periodically. But there's no need to open the case!

For all of these operator-selectable calibrations, you may return to the "factory" settings by holding the "4" button down during power-up. This will reset everything.

The Band Registers

The band registers are all 74HC595 shift registers, which provide parallel output bits but are programmed serially from the MCU. The desired data is set up by writing the desired value to the serial interface, then using a parallel I/O bit to strobe the desired band register. To effect band-switching, the desired band-driver bit is set or cleared, providing voltage to the desired RF assembly through a PNP transistor.

Note that there are more drivers on the board than there are bands to select. This allows for future upgrades and different options.

Rig State (6 bytes)	\$00 \$05
Band Bias (10 x 2 bytes)	\$06 \$19
S-Meter Calibration (10 bytes)	\$1A \$23
Miscellaneous (10 bytes)	\$24 \$2D
Memory Channel 0 (6 bytes)	\$2E \$33
Memory Channel 1 (6 bytes)	\$34 \$39
. . .	
Memory Channel 10 (6 bytes)	\$6A \$6F

Fig 10—EEPROM storage organization.

The Piezo Beeper

Audible feedback for the keypad inputs is supplied by piezo buzzer BZ1, driven by timer output compare 1 pin (TCMP1) of the MCU. The MCU timer has a free-running 16-bit counter that counts the clocks from the MCU oscillator. A timer compare output changes state when the 16-bit timer compare register value matches the value of the free-running counter. This event can also cause an interrupt to the MCU processor core, which can then change the value of the output compare register. In this way a particular frequency can be established on the timer output compare pin, and this is how the piezo buzzer is excited.

The EEPROM

The EEPROM, U5, is a 93C56 serial device. It's used to store the state of the rig when last turned off, calibration data and memory channels. Each memory channel saves the frequency and rig state. The rig state comprises the operating mode (CW, LSB, USB or AM), the frequency band, the state of the preamp (on or off), and the state of AGC (slow or fast). The EEPROM organization is shown in Fig 10.

The +12 V from the main power source feeds into the front-panel board and then gets distributed to various other boards. The PC board itself is a double-sided unit, with plated-through holes and an epoxy silk screen. The board measures 3.1 inches high by 9.85 inches long. This size coincides with an enclosure that Sheldon Hands sells as part of his transceiver.

Other Applications

Although the MCU/DDS board was designed to be used with the Hands RTX10 system, it also can be used with just about anything else that requires a VFO signal from 5 to 5.5 MHz. We mentioned that the 7008 has a bit of noise, but we are talking about stuff that is more than 50 dB down from the output! Since this is a digital generation of the signal, we are talking rock solid stability. Some of the more popular digital HF modes may be an option for that older rig by using this board as an external VFO. Granted, most home-brew designs and kit rigs use a simple FET style VFO, and this board is perhaps a bit of overkill, but it certainly would give you room to grow that special rig.

Notes

[1] Kanga USA, 3521 Springlake Drive, Findlay, OH 45840, tel: 419-423-4606, email: kanga@bright.net, Web: http://qrp.cc.nd.edu/kanga/.

[2] A parts kit for the DDS/MCU board is available from Aero Electronics, 14824 Bear Creek Pass, Austin, TX 78737, tel: 512-288-3220 (7-9 pm CDT). The kit includes: a double-sided PC board with plated-through holes and silk screen, the preprogrammed microcontroller, a 50-MHz AD7008 DDS IC, a shaft encoder, a custom silk-screened keyboard, a 2 × 16 character back-lit LCD display, an S-meter and a complete set of schematic diagrams and parts list. The price of the kit is \$129.95 plus \$6.50 shipping and handling (US money order required, and shipping is available only within North America). For non-US orders, both the RF and DDS/MCU boards are available from Hands Electronics, Tegryn Llanfyrnach, Dyfed SA35 OBL, UK.

Motorola is a registered trademark of Motorola Inc. All product and brand names are registered trademarks or trademarks of their respective holders. □□

More on Parabolic Dish Antennas

Offset dishes, penny feeds and sun noise.

By Paul Wade, N1BWT

Introduction

In the past year, you have probably noticed little gray dish antennas sprouting from rooftops and appearing for sale in stores as part of satellite TV systems. One common version is the RCA DSS system, which uses an 18-inch offset-fed dish.

In previous articles about parabolic dish antennas, I described only conventional axial-feed dishes because other types weren't readily available.[1,2] Now, with the introduction of the DSS system this is no longer true—inexpensive offset-feed dishes are readily available, and they offer excellent performance at 10 GHz.

This article is the "fourth part" of my three-part series of *QEX* articles on practical microwave antennas.[1,3,4] In order to show how to use offset dishes effectively, some familiarity with antenna terminology and concepts is required, so I urge the reader to review the earlier articles. In addition to offset-feed dishes, this article will also discuss the "penny" feed for conventional dishes, dishes with multiple reflectors and the use of sun noise to verify antenna and system performance.

Offset-Feed Dishes

An offset-feed dish antenna has a reflector that is a section of a normal parabolic reflector, as shown in Fig 1. If the section does not include the center of the dish, none of the radiated beam is blocked by the feed antenna and support structure. For small dishes, feed blockage in an axial-feed dish causes a significant loss in efficiency. Thus, we might expect an offset-feed dish to have higher efficiency than a conventional dish of the same aperture.

In addition to higher efficiency, an offset-feed dish has another advantage for satellite reception. The dish in Fig 2, aimed upward toward a satellite, has its feedhorn pointing toward the sky. A conventional dish would have the feedhorn above it, pointing toward the ground, as shown in Fig 3. Any spillover from the feed pattern of the conventional dish would receive noise from the warm earth, while spillover from the offset dish would receive less noise from the cool sky. Since a modern low-noise receiver,

---

[1] Notes appear on page 22.

161 Center Road
Shirley, MA 01464
email: n1bwt@wade.iii.net

such as a satellite TV LNB, has a noise temperature much lower than the earth, the conventional dish will be noisier. This is *G/T*, which I described in the previous series of articles; the offset dish offers higher gain, *G*, since the efficiency is higher, plus reduced noise temperature, *T*, so both terms in the *G/T* ratio are improved. The higher gain means more signal may be received from a source, and the lower noise temperature means that less noise accompanies it, so a higher *G/T* offers a higher signal-to-noise ratio.

The RCA DSS Dish

The original incentive to use an offset-feed dish was provided by Zack Lau, KH6CP, who pointed out that the 18-inch RCA DSS dishes are available by mail order for about \$13.[5] I ordered a dish and a mounting bracket to see if I could figure out how to use one at 10 GHz.[6] When it arrived, it wasn't obvious where the feed point should be, so I took a trip to a local discount store to eyeball the system on display.

Now I had an idea where to put the feed, but not the exact location. The RCA reflector is oval shaped, but Ed, W2TTM, provided the needed insight: the dish aperture should appear circular when viewed on boresight, as shown in Fig 1. Thus the dish must be tilted forward for terrestrial operation. Although the reflector is an oval, the effective antenna aperture is the projected circle, with a diameter equal to the small dimension of the oval, 18 inches for the RCA dish. The tilt angle, feedpoint location and the rest of the dish geometry can be calculated—see the Appendix for the procedure. Version 2 of the *HDL_ANT* computer program will do these calculations. This program is available from the ARRL BBS (860-594-0306) or via the Internet at http://www.arrl.org/qexfiles/hdl_ant2.zip or ftp://ftp.arrl.org/pub/qex/hdl_ant2.zip.

The calculations show the focal length of the RCA dish to be 11.1 inches. If the dish were a full parabola rather than just an offset section, the diameter would be about 36 inches, for an *f/D* of 0.30, which would require a feed with a very broad pattern. However, a feedhorn need only illuminate the smaller angle of the offset section, a subtended angle of about 77°. This subtended angle is the same as a conventional dish with an *f/D* of 0.7, so a feedhorn designed for a 0.7 *f/D* conventional dish should be suitable. Rectangular feedhorns have been shown to work well with offset reflectors and are readily designed to illuminate an *f/D* this large.[7] I used G3RPE's graph for rectangular feedhorn design and the *HDL_ANT* computer program to design suitable rectangular horns.[8,9] I made two of different lengths from flashing copper. Subsequently, I added an approximation to G3RPE's curves to version 2 of *HDL_ANT* so the program can design feedhorns for both offset and conventional dishes as well as generate templates for them.

Since the actual reflector geometry has an *f/D* of 0.30, the focal distance should be quite critical. As explained in part 2 of my previous *QEX* series, this dimension is the most critical for dish antenna performance—even more critical for reflectors with smaller *f/D*—so the phase center of the feed should be positioned within a quarter-wavelength of the focal point.

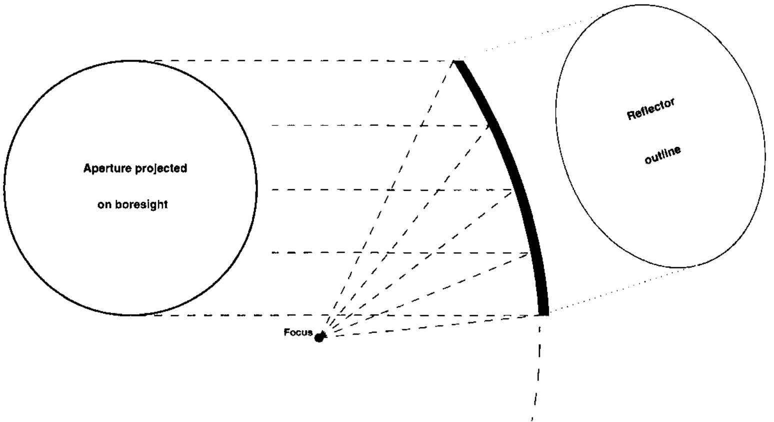


Fig 1—Geometry of an offset parabolic dish antenna.

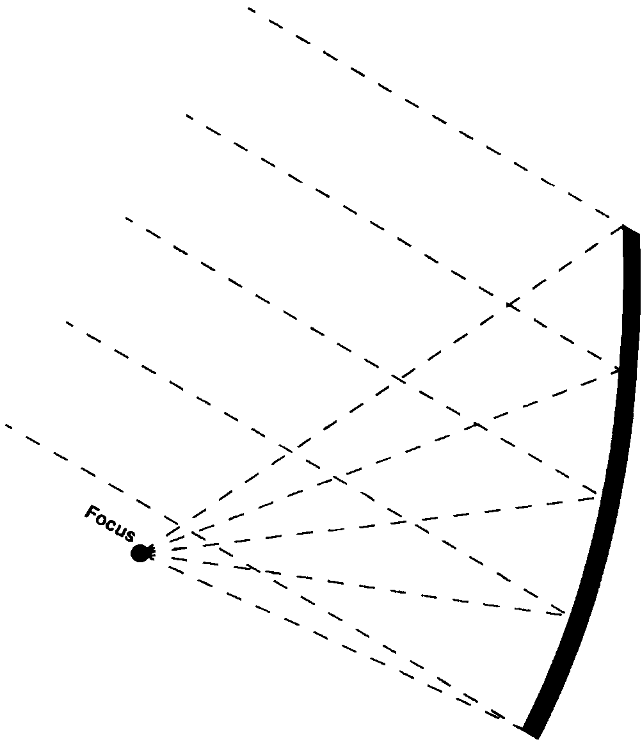


Fig 2—An offset parabolic dish antenna aimed at a satellite.

The RCA dish must be tilted forward to an angle of 66.9° from horizontal for terrestrial operation with the beam on the horizon. In this orientation, the focal point is just below the lower rim of the dish, so the feedhorn is out of the beam. To locate the focus accurately, I calculated the distance to both the top and bottom of the rim, tied a knot in a piece of string and taped the string to the rim so the knot was at the focus when the string was pulled taut, as shown in Fig 4. Then I made a sliding plywood holder for the feedhorn, taped it in place and adjusted it so that the knot in the string was at the phase center of the horn, about 6 mm inside the mouth of the horn, shown in Fig 5. (For visibility, the string in the photograph is much heavier than the kite string I used so a small knot could locate the focus more accurately.) Materials aren't critical when they aren't in the antenna beam!

Where should the feedhorn be aimed? On a conventional dish it is obvious—at the center. However, an offset feed is much closer to one edge of the dish, so that edge will be illuminated with much more energy than the opposite edge. I read an article that did a lengthy analysis of the various aiming strategies and then suggested that

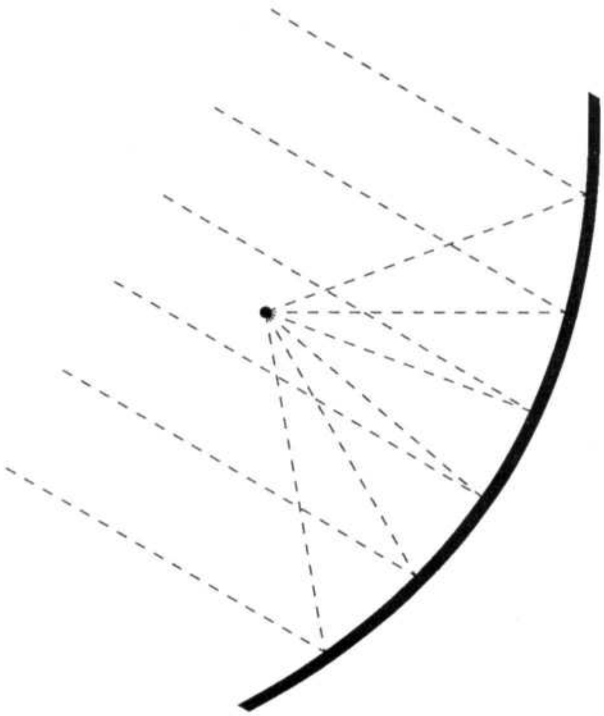


Fig 3—An axial-feed parabolic dish antenna aimed at a satellite.


Fig 4—Locating feed point for offset dish using calculated string lengths.

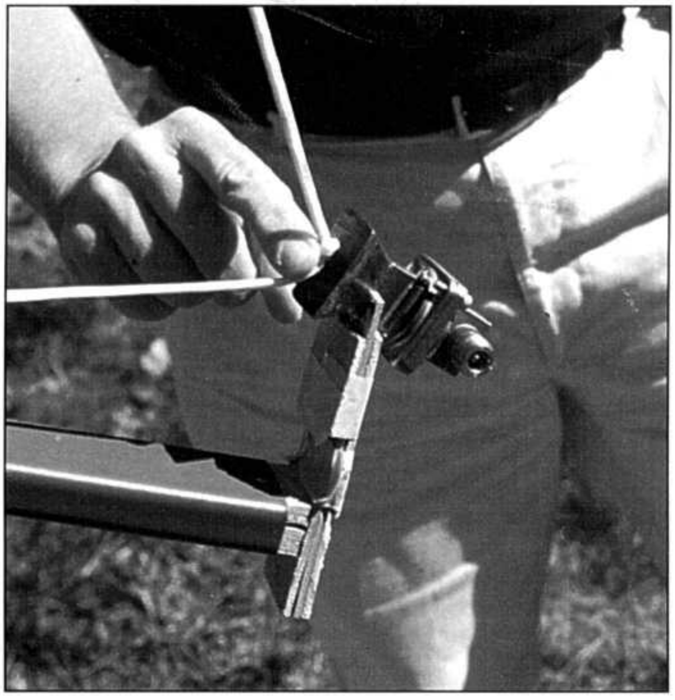


Fig 5—Knot in string accurately locates phase center of feedhorn at focal point of offset dish.

small variations have little effect, so aiming at the center of the reflector is close enough.[10]

After all this analysis, it was time to see if the offset dish really works. We (W1RIL, WB1FKF, N1BAQ, and N1BWT) set up an antenna range and made the measurements shown in Table 1. The RCA dish with a simple rectangular feedhorn measured 63% efficiency at 10 GHz, significantly higher than we've *ever* measured with an 18-inch conventional dish. Varying the focal distance showed that the calculations were correct and that this dimension is critical. Fig 6 is a template produced by the *HDL_ANT* program for the rectangular feed horn that gave the highest efficiency, and Fig 7 is a photograph of the feedhorn I made with the template.

The higher efficiency of the offset-feed dish is mainly due to reduced blockage by the feed and supporting structure. Fig 8 is a photograph of a conventional dish while measuring sun noise, so that the shadow of the feed demonstrates the actual area blocked—neither light nor RF energy from the sun is reaching the reflector. Fig 9 is a photograph of the RCA offset dish peaked on the sun to measure sun noise; note that the shadow of the feed is only a tiny area at the bottom edge. Remember that these feedhorns provide a tapered illumination, so the energy illuminating the center of the reflector is typically 10 dB stronger than at the edge. Thus, central blockage in a conventional dish is *ten times* worse than the same area blocked at the edge of an offset dish, and the photographs clearly illustrate how much more blocked area there is in a conventional axial-feed dish.

Other Offset Feeds

A rectangular feed horn is fine for linear polarization, but what if we want circular polarization? One popular feed that works well with circular polarization is the W2IMU dual-mode feed. The published amateur versions are all for f/D in the range 0.55 to 0.6, but Dick's original article also described another version for a different f/D.[11] It should be possible to make one for the 0.7 f/D needed for the RCA offset dish, but that would require some experimentation (or computer modeling, if you have software available) for optimum performance.

The truly adventuresome could try

Table 1—Summary of 10.368-GHz Antenna Measurements
(Measurements by N1BWT, W1RIL, WB1FKF and N1BAQ, 7/6/95)

Antenna	*Focal Dist*	*Gain (dBi)*	*Efficiency*
Standard-Gain Horn (22.5 dBi calculated gain)[1]		22.45	43%
WB1FKF hombrew horn		22.05	
25-in dish, $f/D = 0.45$, from Satellite City, with the following feeds:			
11 GHz Superfeed[2]	11.187 in	34.3	56%
	11.0 in	34.0	52%
11 GHz Superfeed, modified with central waveguide flush with outer rings.[2]	11.187 in	34.6	61%
G4ALN "penny" feed	10.375	33.0	41.5%
18-in dish, $f/D = 0.42$, from Satellite City, with the following feeds:			
Clavin feed	7.875 in	31.2	53%
18-in offset dish, RCA DSS steel, with the following feeds:			
Rectangular Horn, E=31.2 mm, H=41.1 mm, Length=20 mm			
	11 in[3]	32.0	63.5%
	11.25 in[3]	31.0	50%
Rectangular Horn, E=31.2 mm, H=41.1 mm, Length=10 mm			
		31.5	57%
Rectangular Horn, surplus, E=30.1 mm H=45.2 mm, Length=42 mm			
	11 in[3]	31.8	61%
24-in (WB1FKF) with the following feeds:			
11 GHz Superfeed with Styrofoam housing[2]		34.4	62%
WA1MBA log-periodic		28.0	14%
24-in offset dish, plastic, with the following feed:			
Rectangular Horn, E=31.2 mm, H=41.1 mm, Length=20 mm.			
	14.75 in[3]	34.3	61%
30-in dish, $f/D = 0.45$, (lighting reflector), with the following feeds:			
11 GHz Superfeed, modified with central waveguide flush with outer rings[2]	13.5 in	36.4	64%

Measurement specifications:

Range: Length = 150 feet. $2D^2/\lambda$ = 135 feet. Test height ≈10 feet.

Focal distance: Each feed was adjusted for maximum gain. Axial dish focal distances measured to outermost point on feed.

Notes:

[1] Scientific-Atlanta model 12-8.2. Antenna courtesy KM3T, gain thanks to John Berry of Scientific-Atlanta.

[2] 11 GHz Superfeed is a Chaparral feedhorn for 11-GHz TVRO.

[3] Offset dishes measured from bottom edge of dish to center of horn aperture.

a trimode feed designed specifically for offset-fed dishes.[12] The math is daunting, and construction appears difficult, but I have seen one TVRO feed that may use this design.

Other Offset Dishes

I was given an offset-feed, 24-inch plastic dish with a cosmetic defect (and no other information). Measurements showed the geometry to be similar to the RCA dish, so the same feedhorns would work fine. I was not able to support the feed as well on this dish, so the feed location may not have been optimum, but it still measured 61% efficiency at 10 GHz.

Two other types of offset dishes seem to be fairly common, so some will probably wind up in amateur hands eventually. Many automobile dealerships and discount stores have larger offset dishes, four feet or more in diameter, with a reflector that appears circular. The other type is another brand of TVRO system, with an oddly shaped dish about 3 feet across; the ones I've seen are marked "Primestar." I had a chance to look one over at a county fair, next to the tractor dealer. The reflector appeared to be wider than it was high, requiring a fairly wide feed angle. The feed horn had a curved plastic surface that could possibly be a molded lens.

If I were to acquire one of these reflectors, I would place it flat on the ground with the reflecting surface facing upward and fill it with water, which provides a level surface from which to take measurements. The water should fill an oval area reaching the top and bottom edges of the rim, but not the sides. Measuring this oval as described in the appendix, and measuring the depth and location where the water is deepest, should be enough to calculate the offset geometry. The feedhorn beamwidth would have to be broader from side-to-side than from top-to-bottom, but a rectangular feedhorn can be designed to provide an asymmetric pattern.

Mounting an Offset Dish

To aim an offset dish at the horizon with the feed below the dish, the reflector must be tilted forward—66.9° from horizontal for the RCA dish. One way to accomplish this would be to mount it on a wedge cut at the correct angle, so that the bottom of the wedge

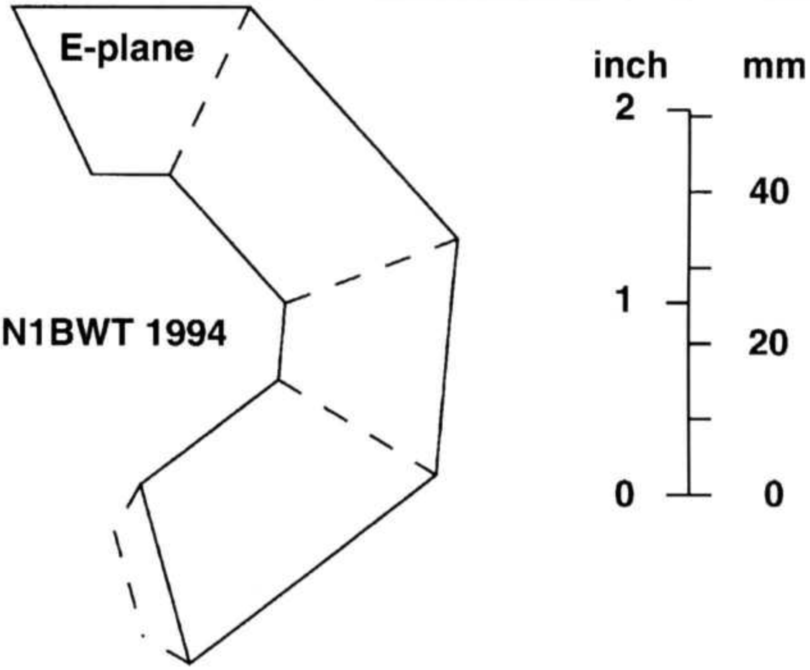


Fig 6—Template for a 10-GHz feedhorn that can be used with the RCA DSS offset dish.

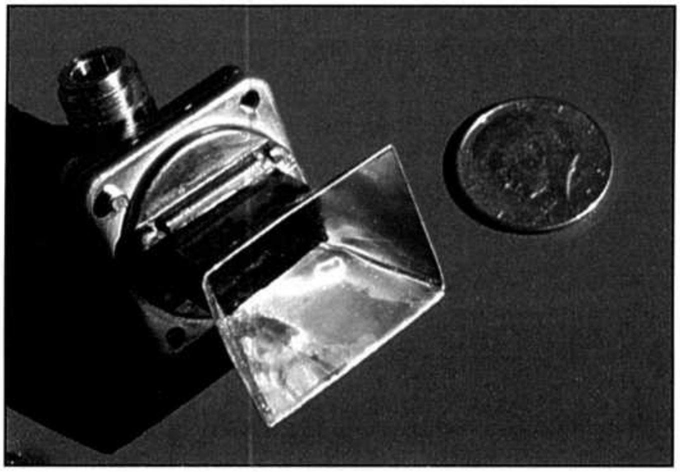


Fig 7—Photograph of 10-GHz rectangular feedhorn for RCA DSS offset dish made using template in Fig 6.

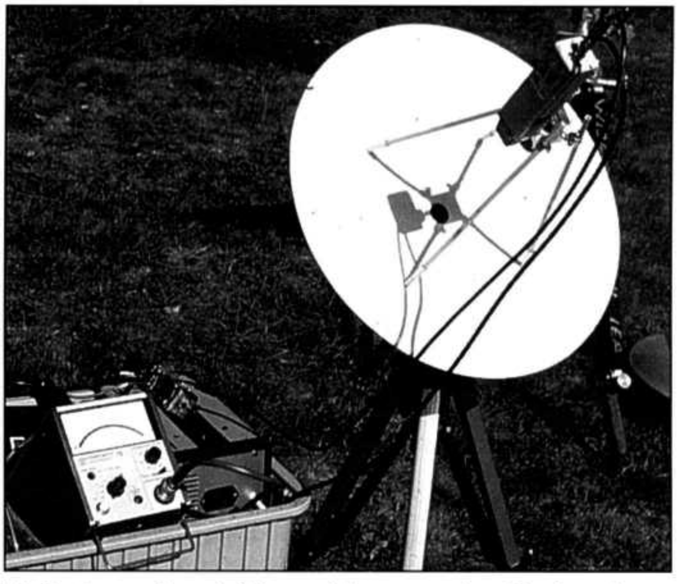


Fig 8—Conventional dish receiving sun noise. Shadow of feedhorn demonstrates aperture blockage by feed.

can be mounted on a level surface or tripod. An alternative technique is to rotate the dish so that the feed is to the side, level with the center of the dish. In this configuration, the elevation uncertainty is eliminated, but an aiming device must be provided for azimuth. An accurate azimuth readout is a good idea for any dish, since aiming a narrow beam by eye is fraught with error. A settable compass rose with one-degree gradations works well for rover operations.

The Penny Feed

The "penny" feed has been used for years with good results. It consists of a metal disc, originally an old (pre-decimalisation) English penny, at the end of a waveguide with slots in the broad wall of the waveguide. I built one to see how well it really works, using dimensions by G4ALN from the *RSGB Microwave Handbook, Volume 3*.[13] The only English coin I had of the right diameter was ten new pence rather than an old penny, but silver should work at least as well as copper. The feed is easy to build, and has a good VSWR, so I can see why it is popular. However, the performance was mediocre, with 41% efficiency, about the same as an open waveguide flange feeding the same dish. Thus, the gain of a 25-inch dish fed with a penny feed is not much higher than the 18-inch offset dish fed with a simple horn.

To be fair, the dish we used, with an *f/D* of 0.45, is not optimum for the penny feed. The *Handbook* states that it is suitable for dishes with an *f/D* ratio in the range 0.25 to 0.3. A dish that deep is extremely difficult to illuminate well, so it is unlikely that this feed will deliver much higher efficiency than we measured. However, it is probably as good a feed as any for very deep dishes.

Cassegrain and Gregorian Feeds

Large professional antennas often use multiple reflector feeds, like the Cassegrain (hyperbolic subreflector) and Gregorian (elliptical subreflector) configurations.[14] Even better is a shaped-reflector system, where both reflector shapes are calculated for best efficiency and neither reflector is parabolic.[15] JPL reports 74.5% efficiency on their 34-meter high-efficiency antenna.[16]

All of these systems require a carefully shaped subreflector that is more difficult than a parabola to fabricate. For a shaped reflector to work well, it must be larger than 10 wavelengths, and the main reflector must be much larger than the subreflector to minimize blockage by the subreflector. One analysis suggested that a Cassegrain antenna must have a minimum diameter of 50 wavelengths, with a minimum subreflector diameter of 20 wavelengths, before the efficiency is higher than an equivalent dish with a primary feed.[17] This is a fairly large dish, even at 10 GHz, and shaping a 20-λ subreflector is beyond the ingenuity of most hams. However, there is probably a surplus one somewhere, and the scrounging ability of hams should never be underestimated.

Sun Noise Measurement

Even a modest 10-GHz system is capable of detecting sun noise, which is an excellent way of ensuring both antenna and receiver performance since we can predict how much sun noise should be received with a given antenna size and receiver noise figure.[18] Only a relatively simple set-up is required to make reasonably accurate sun noise measurements.

On the other hand, setting up an antenna range to evaluate antenna performance, as described in my earlier articles, requires a significant amount of equipment and a good standard antenna of known gain, and it is still one of the most difficult measurements to perform accurately.

A good system for measuring sun noise was described by Charlie,

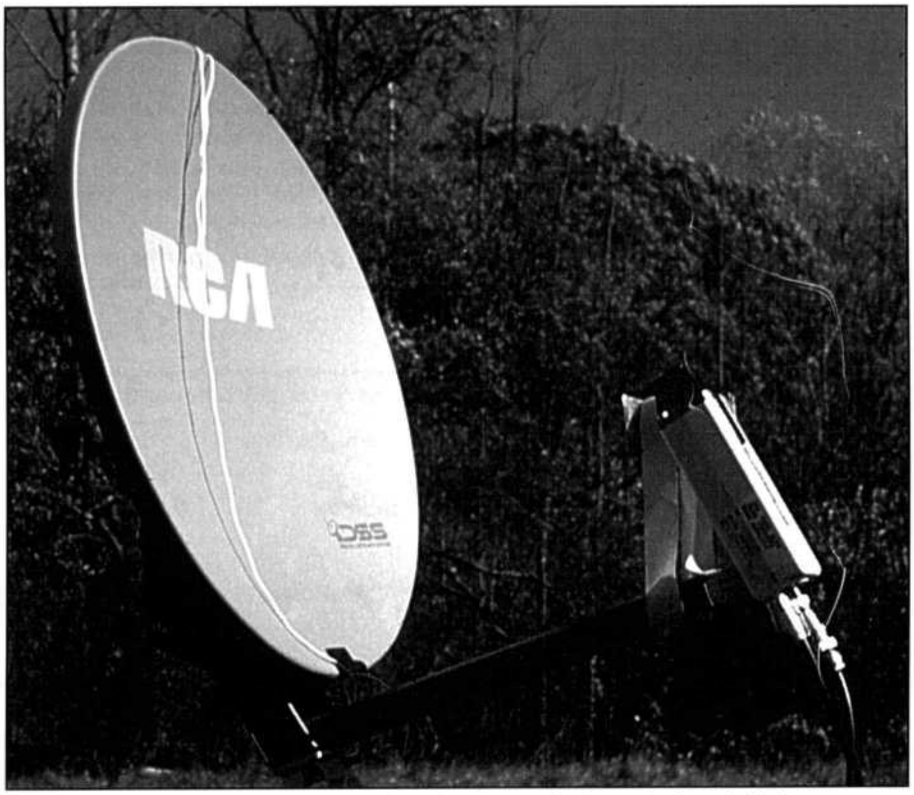


Fig 9—Offset dish receiving sun noise. Feedhorn shadow at edge of dish demonstrates minimal aperture blockage by offset feed.

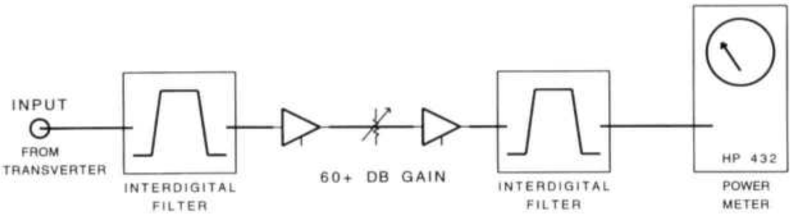


Fig 10—Block diagram of an indicator for sun-noise measurements.

G3WDG.[19] He built a 144-MHz amplifier with moderate bandwidth using MMICs and helical filters that amplifies a transverter output to drive a surplus RF power meter. The newer solid-state power meters, like the HP 432 and more recent models, are stable enough to detect and display small changes in noise level, and the response is slow enough to smooth out flicker. Since my 10-GHz system has an IF output at 432 MHz, duplicating Charlie's amplifier would not work. In the junk box I found some surplus broadband amplifiers and a couple of interdigital filters. I combined these to provide high gain with a few megahertz of bandwidth, arranged as shown in Fig 10. The first filter limits the bandwidth so we are measuring at the desired frequency, 10.368 GHz in this case, and the second filter at the output is important to limit the noise bandwidth at the detector, since noise power is proportional to bandwidth. Without the second filter, the broadband noise generated by the amplifiers or MMICs would overwhelm the sun noise, whose bandwidth is limited by the first filter. Approximately 100 dB of total gain is required with a bandwidth of 10 MHz for an output power of one milliwatt. I found that roughly 60 dB of gain after my preamp and transverter was required to get a reasonable level on the power meter.

Operation is simple—point the dish at the sun, peak the noise, then move to clear sky and note the difference in output. Several precautions are necessary:

1. According to G3WDG, amplifiers with broadband noise output suffer gain compression at levels about 10 dB lower than found with signals, so be sure the amplifier compression point is at least 10 dB higher than the indicated noise.
2. Make sure no stray signals appear within the filter passband.
3. A clear area of sky is necessary, since foliage and other obstructions add thermal noise that can obscure the cold-sky reading. I found a large tree generated more noise than the sun because it filled the whole beam and appeared in sidelobes as well. The measurement is really comparing sun noise plus all other noise to all the other noise received, so stray sources of thermal noise can produce error. Fortunately, this error is almost always in the pessimistic direction, so we aren't led astray.
4. If the preamp is at or near the feed, don't let it heat up too much or its noise temperature can change. (Total solar radiation is about one kilowatt per square meter—that's several hundred watts on even a small dish.)

Before making measurements, I used the *NOISE* program by Mel, WR0I, to estimate expected sun noise.[18] For a 2-foot dish with 60% efficiency and a receiver noise figure of about 2.5 dB (modified TVRO LNB), the program predicted 2.4 dB of sun noise. My initial measurements using the setup described below showed 2.5 dB of sun noise on my 25-inch dish and 2.0 dB with the 18-inch, offset-fed RCA dish. However, I also measured 2.2 dB of sun noise on a 30-inch dish with a fancy "shepherd's crook" feed arrangement using copper water pipe as circular waveguide. The last measurement quickly highlighted the need for further adjustment of the feed arrangement. The version of the *NOISE* program I used only calculates for dish sizes in integral feet, so we can't get precise estimates for these small dishes, but Mel has promised an improved version.

After I made the equipment more portable and stable, I was able to measure sun noise on most of my 10-GHz antennas, with the results shown in Table 2. The *G/T* advantage of the offset dish for satellite communication is

Table 2: More Sun Noise Measurements

22 Oct 1995, 1:00 PM

Antenna	*Sun noise*
Standard Gain Horn	0.35 dB
30-inch dish, mod. Chaparral feed	3.2 dB
25-inch dish, Chaparral feed	2.3 dB
18-inch dish, Clavin feed	1.6 dB
18-inch offset—steel, rect. horn feed	2.4 dB
18-inch offset—SMC, rect. horn feed	2.5 dB

Note: Estimated noise figure = 2.9 dB

Table 3—N1BWT Recommendations for Dish Feeds

Type of Feed	*f/D Optimum*	*Best η estimate*	*η for f/D=0.45*	*Comments*
Chaparral	0.35-0.45	55-65%	61-64%	"11 GHz Superfeed" from Chaparral dealers good at 10 GHz
VE4MA/Kumar	0.35-0.45	55-65%	61%	proven performance at 1296, 2304, and 3456 MHz
W2IMU Dual-Mode	0.5-0.6	55-60%	NR	proven performance 432 MHz to 10 GHz
Rectangular horn	>0.45	50-60%	58%	tailor dimensions for *f/D* —also good for Offset dishes
Clavin	0.35-0.4	50-60%	57%	small feed blockage
EIA Dual-dipole	0.5-0.6	50-60%	NR	better at lower frequencies
Circular horn	Function of diameter	25-50%	26%	asymmetrical E- and H-planes and phase centers; of diameter better with choke flange
Penny (G4ALN)	0.25-0.3	30-45%	41.5%	attractive mechanically
Dipole	0.3-0.4	30-45%	NR	asymmetrical E- and H-planes
Log Periodic	?	10-40%	14%	broadband, but poor phase centers

clearly demonstrated: the 18-inch offset dish is not only much better than the equivalent size conventional dish, but outperforms a 25-inch conventional dish that has 2 dB more gain, as shown in Table 1.

Sun-noise measurements are fine for checking system performance but less satisfactory for making adjustments. Any adjustment may change both sun and sky reading, so it is necessary to compare the two after each adjustment, and the resulting differences may be small. Make one adjustment at a time, keep careful notes and look for reproducible improvements. The process is tedious, but careful work pays off.

If you've never tried it, you are probably wondering why you can't just use your receiver to measure sun noise. The answer is that you can, but with less accuracy and more frustration because of the narrow bandwidth and short time constant of a communications receiver. First, the noise-measuring equipment described above has a bandwidth of a few MHz, while a typical receiver bandwidth is 3 kHz, a thousand times narrower. To compensate for a thousand times narrower bandwidth, a thousand times more gain, or 30 dB more, is required. Most receivers have adequate gain but use AGC to control the gain; if you can't turn off the AGC, a problem with many receivers, the audio output doesn't change linearly with input level, and the S-meter is far too small to resolve tenths of a dB. With the AGC off, the audio output follows the input noise, but the narrow bandwidth and short time constant (about one millisecond, limited by the lowest audio frequency response, typically 300 Hz) produce an output with fluctuations caused by the random nature of noise—I've typically seen one dB of flicker, making it hard to read tenths of a dB. With the power meter, the thermistor sensor has a time constant of hundreds of milliseconds, which smoothes and averages the flicker to produce a very stable meter indication.

Measurements and Calculation for an Offset Parabolic Reflector

The geometry of an offset-feed dish antenna is a bit more complicated than a conventional dish antenna, but the measurements needed to use one are straightforward. We need to first determine the tilt angle of the reflector, then do some curve fitting calculations for the dish surface, calculate the focal length and finally determine the focal point in relation to the offset reflector.

One common type of offset parabolic reflector has an oval shape, with a long axis from top to bottom and a shorter axis from side to side. However, if you were in the beam of this antenna, looking down the boresight, it would appear to be circular, with the feed at the bottom. Tilt the top of the reflector forward, until it appears circular from a distance, and it will be in the correct orientation to operate with the beam on the horizon. The tilt can be determined much more accurately with a simple calculation:

Tilt angle (from horizontal) = *arcsin* (short axis / long axis) [Note: the *arcsin* function is called sin^{-1} on some scientific calculators.]

For the RCA 18-inch dish, the short axis is 460 mm (about 18 inches) and the long axis is 500 mm. Therefore, the tilt angle = *arcsin* (460/500) = 66.9° above horizontal. At 10 GHz, one millimeter is sufficiently accurate for most dish dimensions, so using millimeters for calculations eliminates a lot of tedious decimals.

If the offset reflector is not oval, we can still use the same calculation by placing it on the ground with the reflecting surface upward and filling it with water; the surface of the water is a level plane from which to make measurements. The surface of the water in the dish should be an oval just touching the top and bottom rims, while the other axis of the oval of water is the shorter axis.

The other dimension we need is location and depth of the deepest point in the dish. The deepest point is probably not at the center, but somewhere along the long axis. Using a straightedge across the rim for an oval dish, or the water depth for other shapes, locate the deepest point and measure its depth and distance from the bottom edge on the long axis.

For the RCA dish, the deepest point is 43 mm deep at 228 mm from the bottom edge on a line across the long axis.

When the dish is tilted forward to 66.9° above horizontal, the translated coordinates describe the curve of the long axis by three points:

0, 0 mm	(bottom edge)
49.8, 226.6 mm	(deepest point)
196, 460 mm	(top edge)

If we assume that the bottom edge is not at the axial center of a full parabola of rotation (the equivalent conventional dish of which the offset dish is a section), but rather is offset from the center by an amount X_0, Y_0, then all three points must fit the equation:

$$4 * f * (X+X_0)=(Y+Y_0)^2$$

The unknowns are X_0, and Y_0, and f, the focal length; plugging in the three points gives us three equations and three unknowns, a readily soluble 3x3 matrix (actually, the 0,0 point allows reduction to a 2x2 matrix, even easier, followed by a simple calculation for X_0 and Y_0). Version 2 of the **HDL_ANT** program will do the calculations for you.

For the RCA dish, the answers are:

f = 282.8 mm = 11.13 inches

X_0 = 0.1 mm behind bottom edge

Y_0 = 11 mm below bottom edge, so the feed doesn't block the aperture at all

So, we tilt the dish to 66.9° from horizontal, and the feed is on a line 11 mm below the bottom edge of the dish. To help locate the focal point, it is 283 mm from the bottom edge and 479 mm from the top edge, both edges on the long axis. I tied a knot in a piece of string and taped it to the top and bottom edges so that the knot locates the focal point.

For the RCA dish, we can also calculate the illumination angle to be 77° on the long axis and 79° on the short axis, so it is roughly symmetrical. The optimum feed for this illumination angle is equivalent to an axial-feed dish with $f / D \cong 0.7$.

Although the illumination angle is equivalent to an $f / D \cong 0.7$, the surface is a section of a parabola about 37 inches in diameter with a focal length of about 11 inches. Thus, the real f / D is 0.3, so the focal distance is quite critical.

Receiver Noise Figure Using the Sun Noise Equipment

The same equipment used for measuring sun noise can also be used to measure receiver noise figure. While measuring sun noise, I noticed that pointing an antenna at the ground produced a significant noise increase. I then realized that this is similar to a hot/cold system for noise figure measurement, where the earth is about 290 K while the cold sky at 10 GHz is around 6 K at high elevations, so the temperature difference is nearly 290 K.[20] Using the standard-gain horn, I found approximately 3 dB of difference between cold sky and warm earth; I had previously measured this LNB preamp at 2.9 dB of NF, or just under 290 K of noise temperature, so a 3-dB increase is exactly right, as shown by the following calculations.

The difference between the hot and cold noise sources is called the Y factor; this is used to calculate the receiver noise temperature, T_e, as follows:

$$T_e = \frac{T_{ground} - Y \cdot T_{sky}}{Y - 1}$$

where Y is a power ratio (convert from dB).

The noise temperature is easily converted to noise figure, F, if you prefer:

$$F(dB) = 10 \cdot log\left(\frac{T_e}{290} + 1\right)$$

This technique should work with any antenna with reasonably high gain and low sidelobes, so stray noise is minimized. A long horn is a good choice. Just point the antenna at clear sky overhead, away from the sun or any obstruction, note the meter reading, then point the antenna into the ground and read the noise increase Y. For convenience, I've added these calculations to version 2 of *HDL_ANT*.

Azimuth Alignment Using the Sun

Computer programs are available that will calculate the sun's azimuth and elevation at a given place and time, so peaking on the sun can be used to calibrate both azimuth and elevation readout. For a rover without a computer, a previously calculated list giving azimuth at half-hour increments at expected rover locations is useful for setup in each location. Don, WB1FKF, suggests that if you are unable to measure sun noise, a vertical line on the dish will suffice on sunny days; simply line up the feedhorn's shadow on the line.

Recommendations for Parabolic Dish Feeds

Table 3 is an update of the recommendations I made for dish feeds in previous articles. The numbers shown are my best estimates for small dishes at 10 GHz, and the recommendations should be taken as my personal opinion only. See the previous *QEX* articles for the appropriate references.

Conclusion

The new DSS offset-feed dishes are readily available small microwave dishes, and I have shown how to use them as high-performance 10-GHz antennas. Their high performance, convenient size and low cost should make them the antenna of choice for portable operation.

Sun-noise measurement capability is a valuable tool for measuring and verifying performance of both antennas and receivers, and for antenna alignment. Also, since it is much easier to achieve accurate results with sun noise than with traditional antenna-range measurements, the various VHF conferences might consider using sun noise for antenna measurement.

Notes

[1] Wade, P. C., N1BWT, "Practical Microwave Antennas, Part 2," *QEX,* October 1994, pp 13-22.

[2] Wade, P. C., N1BWT, "High-Performance Antennas for 5760 MHz," *QEX,* January 1995, pp 18-21.

[3] Wade, P. C., N1BWT, "Practical Microwave Antennas, Part 1," *QEX,* September 1994, pp 3-11.

[4] Wade, P. C., N1BWT, "Practical Microwave Antennas, Part 3," *QEX,* November 1994, pp 16-24.

[5] Lau, Z., KH6CP/1, "RF," *QEX,* March 1995, p 24.

[6] MCM Electronics, 650 Congress Park Drive, Centerville, OH 45459, 800-543-4330. Steel dish part number 221196 or 221197, mounting bracket part number 221199. SMC dish part number 221198, mounting bracket part number 221200.

[7] Huang, J., Rahmat-Samii, Y. and Woo, K., "A GTD Study of Pyramidal Horns for Offset Reflector Antenna Applications," *IEEE Transactions on Antennas and Propagation,* AP-31, March 1983, pp 305-309.

[8] Evans, D., G3RPE, "Pyramidal horn feeds for paraboloidal dishes," *Radio Communications,* March 1975. (Also in Note 9.)

[9] Dixon, M. W., G3PFR, *Microwave Handbook, Volume 3,* RSGB, 1992, p 18.85.

[10] Jamnejad-Dailami, V. and Rahmat-Samii, Y., "Some Important Geometrical Features of Conic-Section-Generated Offset Reflector Antennas," *IEEE Transactions on Antennas and Propagation,* AP-28, November 1980, pp 952-957.

[11] Turrin, R. H., (W2IMU), "Dual Mode Small-Aperture Antennas," *IEEE Transactions on Antennas and Propagation,* AP-15, March 1967, pp 307-308.

[12] Rudge, A. W. and Adatia, N.A., "Offset-Parabolic-Reflector Antennas, A Review," *Proceedings of the IEEE,* December 1978, pp 1592-1618.

[13] Dixon, M. W., G3PFR, *Microwave Handbook, Volume 3,* RSGB, 1992, pp 18.85-18.86.

[14] Hannan, P. W., "Microwave Antennas Derived from the Cassegrain Telescope," *IRE Transactions on Antennas and Propagation,* AP-9, March 1961, pp 140-153.

[15] Williams, W. F., "High Efficiency Antenna Reflector," *Microwave Journal,* July 1965, pp 79-82.

[16] Rafferty, W., Slobin, S. D., et al, "Ground Antennas in NASA's Deep Space Telecommunications," *Proceedings of the IEEE,* May 1994, pp 636-645.

[17] Rusch, W. V. T., "Scattering from a Hyperboloidal Reflector in a Cassegrainian Feed System," *IEEE Transactions on Antennas and Propagation,* AP-11, July 1963, pp 414-421.

[18] Graves, M. B., WR0I, "Estimating Sun Noise at Various Frequencies, Based on the 10.5 cm Flux Reported by WWV," *Proceedings of Microwave Update '94,* ARRL, 1994, pp 125-131.

[19] Suckling, C., G3WDG, "144 MHz wideband noise amplifier," *DUBUS,* 2/1995, pp 5-8.

[20] Graves, M. B., WR0I, "Computerized Radio Star Calibration Program," *Proceedings of the 27th Conference of the Central States VHF Society,* ARRL, 1993, pp 19-25.

PHEMT Preamp for 9 cm

Reprinted from Dubus Technik IV, *Preamps and Receivers.*

By Rainer Bertelsmeier, DJ9BV

Abstract

A preamp equipped with a PHEMT provides top-notch performance in noise figure and gain as well as unconditional stability for the 9-cm band. The noise figure is 0.45 dB at a gain of 14 dB. It utilizes the NEC NE42484A C-band PHEMT and provides a facility for an optional second stage on board. With the new HP GaAs-MMIC MGA86576, the second stage can boost the gain to about 38 dB in one enclosure. The preamp is rather broadband and can be used from 3400 to 3700 MHz.

Glücksburger Str 20
D-22769 Hamburg
Germany

Circuit Description

The construction of this LNA follows the proven design of a 23-cm HEMT-LNA using a wire loop with an open stub as an input circuit.[1] The FET's grounded source requires a bias circuit to provide the negative voltage for the gate. A special active bias circuit is integrated into the RF board that provides regulation of voltage and current for the FET.

This design is very similar to a 13-cm preamp described previously.[2] All of the needed details are contained in this article, however.

LNAH-3.4-N424

The design (Fig 1) is basically the same as that of the 13-cm PHEMT preamp. The difference is an additional matching stub, ST2, in the output.

Quarter-wave stub ST3 provides a short on 3.4 GHz. On all frequencies outside the operating range the gate structure is terminated by R1. Dr. 1 is a printed λ/4 choke that decouples the gate bias supply.

C4 provides a short on 3.4 GHz because it's in series resonance. On all frequencies outside the operating range the drain structure is terminated by R3. Dr. 2 is a printed λ/4 choke that decouples the drain-bias supply.

LNAH-3.4-N424/865

The two-stage version (Fig 2) uses an HP GaAs-MMIC MGA86576 in the second stage. This MMIC is able to

---

[1] Notes appear on page 26.

provide 23 dB of gain with about 2 dB of noise figure. The input is matched by a wire loop for optimum noise figure. The output is terminated by a resistor, R5, and a short transmission line, L10. Together with L7, L8 and C3, this resuls in a good measured output return loss. The MMIC typically adds 0.1 dB to the noise figure of the first stage. This is somewhat difficult to measure; most converters will exhibit gain compression when noise power from the noise source is amplified more than 40 dB before entering the converter.

Construction

The circuit is constructed using a microstripline technique on a 0.79-mm thick glass PTFE substrate, Taconix TLX. (See Figs 3 and 5.) An active bias circuit, which provides constant voltage and current, is integrated into the PC board (Fig 4). The dimension of the PC board is 34×72 mm.

LNAH-3.4-N424

Refer to the parts layout in Fig 3 to construct the preamp as follows:

1. Prepare a PC board to fit into an aluminum box.
2. Prepare holes for the SMA connectors. Note that the input and output connector are asymmetrical. Use the PC board to mark the connector positions.
3. Drill holes for through contacts (0.9-mm diameter) in the PC board and connect through with 0.8-mm CuAg (silver-plated copper) at the indicated positions.
4. Solder all resistors onto the PC board.
5. Solder all capacitors onto the PC board.
6. For L1, cut a 9-mm length of CuAg, 0.25-mm diameter wire. Bend down a 0.5-mm length at each end to 45°. Form the wire into a half-circle loop as shown in Figs 3 and 5. Solder the wire into the circuit with 1-mm of clearance from the PC board. The wire loop has to be flush with the end of the gate stripline and should be soldered at a right angle to it. The wire loop has to be oriented flat, *parallel* to the PC board.
7. Verify the open-loop functioning of the bias-circuit. Adjust P1 to 50 Ω. Solder a 100-Ω test resistor from the drain terminal on the PC board to ground. Apply +12 V to IC1 and measure +5 V at the output of IC1, −5 V at IC2 pin 5, −2.5 V at the collector of T1, +3.1 V at the emitter of T1, +2.5 V at the base of T1, −2.5 V at R17 and +2.0 V across the 100-Ω resistor. If

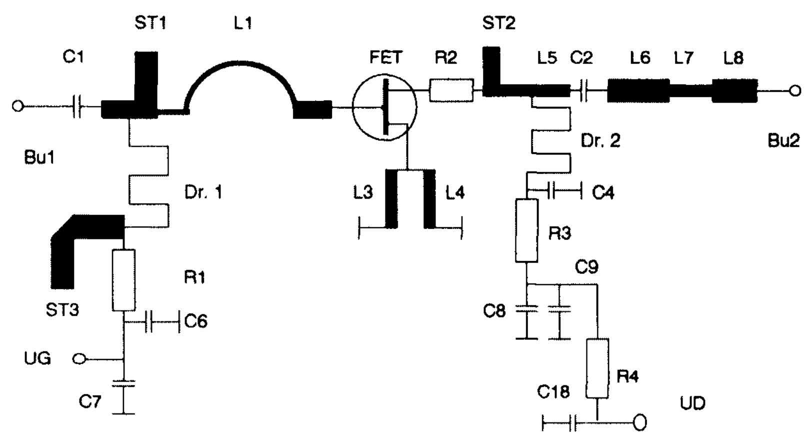


Fig 1—Circuit of LNAH 3.4 N424.

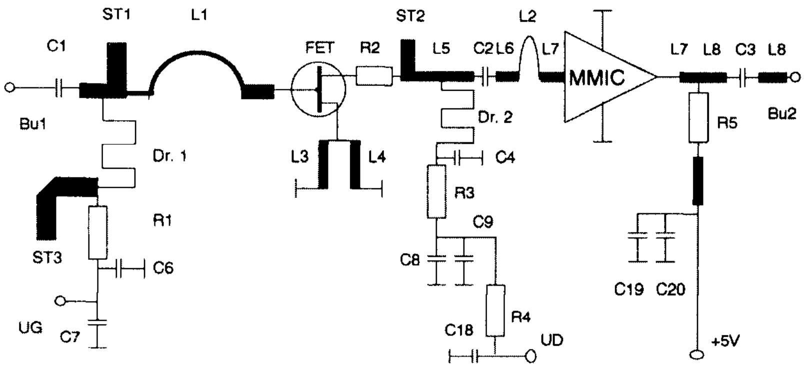
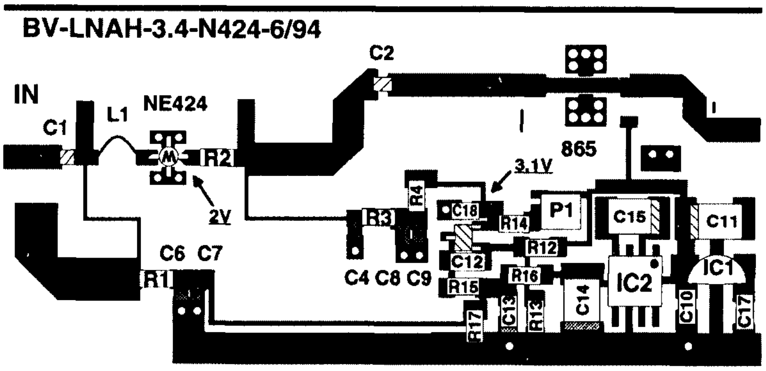


Fig 2—Circuit of LNAH 3.4 N424/MGA865.



L1: 9mm, 0.25mm CuAg, 1 mm above PCB

■ Contact Through with 0.8mm CuAg

Fig 3—LNAH 3.4 N424 parts layout.

okay, remove the 100-Ω test resistor.

8. Solder PHEMT NE424 onto the PC board. Use only an insulated soldering tool and ground the PC board, your body and the power supply of the soldering tool. Never touch the PHEMT at the gate—only at the sources or the drain—when applying it to the PC board and solder fast (less than 5 seconds).

9. Mount the finished PC board into the box. Use M2 or M2.5 screws.

10. Mount the SMA-connectors. Cut the inner conductor to 1 mm of free length. Solder to the striplines with as little solder as possible.

11. Mount the feed through capacitor into the box.

12. Connect D1 between the feed through capacitor and the PC board.

13. Connect the 12-V B+ and adjust P1 for a 16-mA drain current (measure 160 mV across R4 on the RF board). Voltages should be around +2.0 V at the drain terminal, –0.4 V at the gate and +3.1 V at the emitter of T1.

14. Connect the LNA to a noise-figure meter—if you have one—and adjust the input wire loop. Change the clearance to the PC board, as well as the drain current, by adjusting P1 for minimum noise figure. Even without tuning, the noise figure should be within 0.1 dB of the minimum because of the limited tuning range of the wire loop.

15. Glue conducting foam into the inside of the top cover and attach it to the top of the box.

16. Your small wonder is now finished.

LNAH-3.4-N424/865

Refer to the parts layout in Fig 5 and construct as follows:

1. Prepare the PC board by cutting slits into the microstriplines around the MGA865. These are: a 2-mm slit for L2, a 1.8-mm slit for the MMIC and a 0.8-mm slit for C3.

2. For L2, cut a 3.5-mm length of CuAg, 0.25-mm diameter wire (100-mil wire-wrap wire with the insulation removed). Form the wire into a half-circle loop as shown in Fig 5. Solder the wire loop into the circuit. The wire loop has to lie flat on the PC board, be flush with the end of the gate stripline and should be soldered at a right angle to it.

3. Follow the other instructions given above for the single-stage version.

Measurement Results

Noise Figure and Gain

Measurements were taken using an

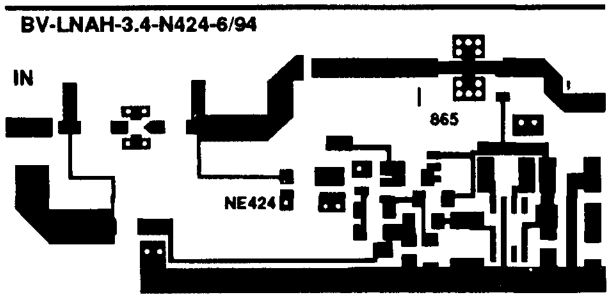


Fig 4— LNAH 3.4 N424 PC board.

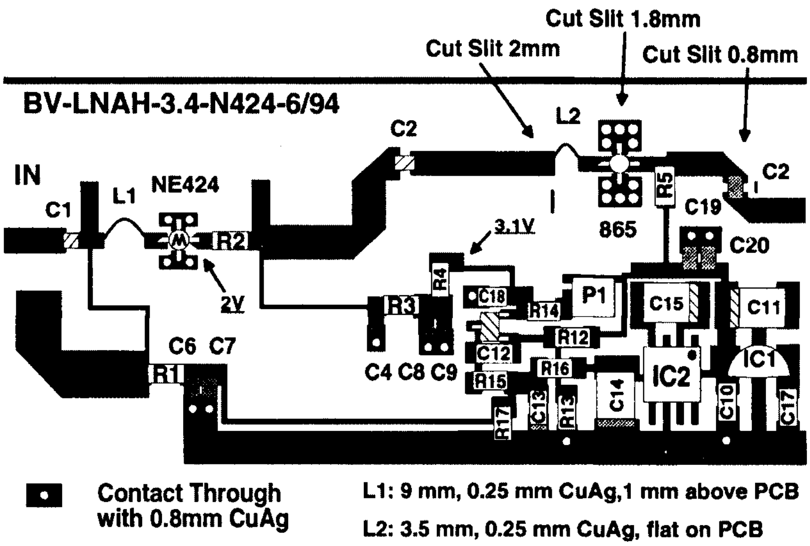


Fig 5—LNAH 3.4 N424/865 parts layout.

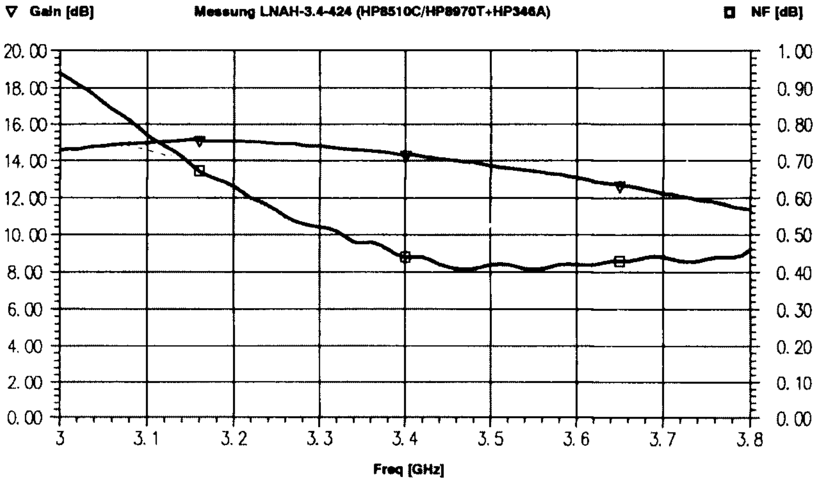


Fig 6—Measured noise figure and gain of the LNAH 3.4 N424.

HP8510 network analyzer and an HP8970B/HP346A noise-figure analyzer, transferred to a PC and plotted.

Figs 6 and 7 show the measurement results for the gain and noise figure for the one-stage and two-stage versions, respectively. Using a special NEC NE42484A C-band PHEMT, a typical noise figure of 0.45 dB at a gain of 14 dB can be measured at 3.4 GHz. An optional second stage on the same PC board with an HP MGA86576 GaAs-MMIC will boost the gain from 14 db to 37 dB. The noise figure of the two-stage version measures 0.55 dB. This version can be used for satellite operation. For EME, where lowest noise figure is at a premium, a cascade of two identical one-stage LNAs may be more appropriate.

Both versions are rather broadband. They can cover various portions of the 9-cm amateur band from 3400 to 3700 MHz without retuning.

Stability

A broadband sweep from 0.2 to 20 GHz shows a stability factor K of not less than 1.6, and the B1 measure was always greater than zero (Fig 8). These two properties indicate unconditional stability.

The two-stage version with the MGA865 measures K>4 at all frequencies.

In reviewing articles in amateur publications, it seems to me that the issue of the necessary broadband stability is not very often tackled in amateur design of preamps.

Conclusions

The 9-cm preamp can achieve a noise temperature as low as 30 K by using a low-cost and rugged C-band PHEMT. Similar results were achieved with the NE326 X-band PHEMT, which is more expensive and not as rugged as the NE424. Also, ample gain is available by means of the optional MMIC second stage. However, the preamp then becomes a tuned device and requires a noise-figure meter for alignment.

Acknowledgements

I'd like to thank Dr. U. L. Rohde, KA2WEU/DJ2RL, Compact Software Inc, and its German distributor, Klaus Eichel, DL6SES/KF2OO, TSS, for supplying the *Microwave Harmonica* software: It proved to be an excellent tool for the design. Thanks, too, to Rainer Jäger, DC3XY, for providing kits, and last but not least, Dieter Briggmann, DC6GC, for the professional measurement of S-parameters and noise figures. Without their help this work would not have been possible.

References

Parts, kits and PC boards are available from Rainer Jäger, DC3XY, Breslauer Str 4, D-25479 Ellerau, Germany, tel: +49 41 0673430. Ready-made and calibrated units are available from Frank Schreyer, DD1XF, Maimoorweg 32, D-22179 Hamburg, Germany, tel: +49 40 6428253.

[1]Bertelsmeier, R., DJ9BV, "HEMT LNAs for 23cm," *DUBUS TECHNIK IV*, pp 177-190.

[2]Bertelsmeier, R., DJ9BU, "PHEMT Preamp for 13 cm," *QEX*, October 1995, pp 7-11.

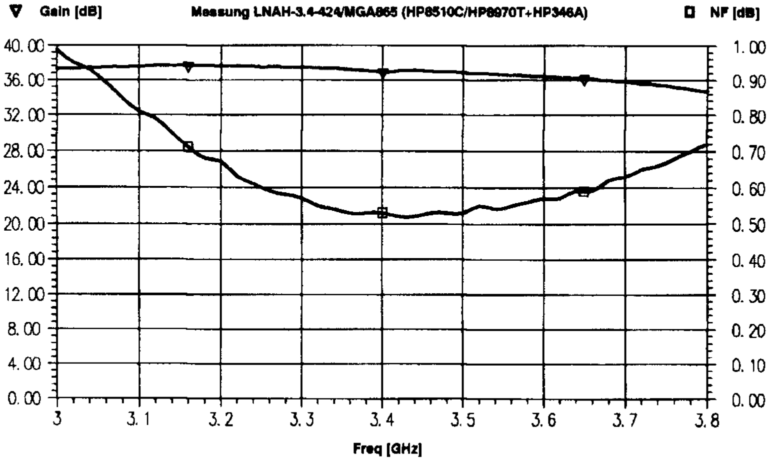


Fig 7—Measured noise figure and gain of the LNAH 3.4 N424/MGA865.

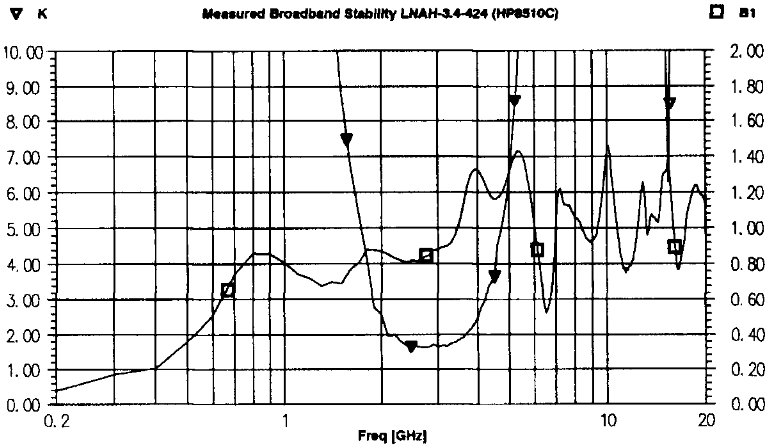


Fig 8—Broadband stability from 0.2 to 20 GHz of the LNAH 3.4 N424.

Table 1: Parts List of LNAH-3.4-N424/865

Part-No.	Type	Value	Manufacturer	Package
C1	Chip-C 50mil	1 pf (500 CHA 1R0 JG)	Tekelec	CHA
C2,3	SMD-C	1.5 pF	Sie	0805
C4	SMD-C	1.8 pF	Sie	0805
C6	SMD-C	100 pF	Sie	0805
C7, 8, 19	SMD-C	1000 pF	Sie	0805
C9, 18, 20	SMD-C	10 nF	Sie	0805
C10, 12, 17	SMD-C	0.1 µF	Sie	1206
C11, 14, 15	SMD-Elco	10 µF	Sie	1210
C13	SMD-Elco	1 µF	Sie	1206
C16	Feed-Thr.	1000 pF	Sie	
R1	SMD-R	47 Ω	Sie	1206
R2	SMD-R	33 Ω	Sie	1206
R3	SMD-R	22 Ω	Sie	1206
R4,5	SMD-R	10 Ω	Sie	1206
R12,13,15	SMD-R	10 kΩ	Sie	1206
R14	SMD-R	68 Ω	Sie	1206
R16,17	SMD-R	22 kΩ	Sie	1206
P1	SMD-Pot	100 Ω	Murata	4310
L1	Wire Loop	0.25 mmCuAg, 9 mm long, 1 mm above PCB	Homemade from Wirewrap	
L2	Wire Loop	0.25 mmCuAg, 3.5 mm long, on PCB	Homemade from Wirewrap	
D1	Diode	1N4007	Mot	
FET	GaAs-FET	NE42484A	NEC	
MMIC	GaAs-MMIC	MGA-86576	HP	
T1	PNP	BC807,856,857,858,859	Sie	SOT-23
IC1	Regulator	uA7805A	Mot	TO-92
IC2	Inverter	LTC1044SN8 (ICL7660SN8)	LT (Intersil)	SO8
Bu1,2	Coaxial	SMA	Suhner/Rosenberger	
PCB	Teflon PCB, Taconix TLX	34 x 72 mm, 0.79 mm, Er=2.55, -LNAH-3.4-N424	DC3XY	
G	Box, Aluminium, Machined	34x72x30 mm	DC3XY	

All Parts except D1, C20 and uA7805A are SMD-Parts

Measurements: LNAH 3.4 N424

9-cm One-Stage Version

Device: NE42484A
Noise Figure: 0.45 dB typically at 3400 MHz
Gain: 14 db typically at 3400 MHz
Input RL: 10 dB
Output RL: 16 dB
Bandwidth: NF<0.55 dB from 3.3 to 4.0 GHz
Stability K: >1.6 from 0.2 to 20 GHz
Supply Current: 20 mA

9-cm Two-Stage Version

Devices: NE42484A and MGA86576
Noice Figure: 0.55 dB typically at 3400 MHz
Gain: 37 dB typically at 3400 MHz
Input RL: 7 dB
Output RL: 23 dB
Bandwidth: NF<0.65 dB from 3.3 to 3.9 GHZ
Stability K: >4 from 0.2 to 20 GHz
Supply Current: 38 mA

□□

1995 Index

January 1995 to December 1995 QEX
(Issues 155 through 166)
All dates are 1995 unless otherwise indicated.

Digital Communications (Price)

Amateur Equipment Prices via the WWW: Aug, 24
Book of *Linux*—Chapter 1, The: Apr, 18
Hardware Interface for Software People, A: Aug, 21
Little Grumping, A: Feb, 28
Omnidirectional Antennas: Aug, 24
P3D: Feb, 24
Phase 3D Showcase in Orlando: Oct, 23
Recharging the Batteries: Oct, 23
Spread Spectrum: It's Not Just for Breakfast Any More!: Jun,22
TANSTAAFL: Feb, 25
TANSTAAFL from NK6K: Jun, 27
Where Everybody Knows Your Name: Feb, 24
Who Watches the Watchers?: Feb, 27

Empirically Speaking (Bloom)

ARRL Electronic Sources: Nov, 2
AMSAT's Phase IIID Satellite: Jan, 2
DOS versus Windows: Oct, 2
DSP Tools Abound: Aug, 2
DSP versus GP: Sep, 2
Electronic *QEX*?: Dec, 2
Get the Net: Feb, 2
Getcha Red Hot Info!: Jun, 2
HF Automation Arrives: May, 2
Incredible Latemess of *QEX*, The: Jul, 3
Licensed to Experiment: Mar, 2
Linux Rules: Apr, 2
Need Technical Information?: Nov, 2
Summertime and the Living is...Hot!: Jul, 2

Feedback

Dynamic Resistance in RF Design (September 1995): Dec, 29
Effect of Local Terrain on HF Launch Angles, The (July 1995): Aug, 13
Graphic Method for Calculating Z (May 1995): Nov, 12
Simple Frequency Deviation Meter Using Time-Domain Techniques, A (Aug 1995): Nov, 12
Torque Capacity of Keyed Rotator Shafts (June 1995): Jul, 29

Miscellaneous Technical

1995 Index: Dec, 28
Band-Stop Filters for Attenuating High-Level Broadcast-Band Signals (Wetherhold): Nov, 3
Designing and Building High-Performance Crystal Laddler Filters (Makhinson): Jan, 3
Designing the Toroid Transformer for the Directional Coupler (Sabin): May, 9
Dual Mixer for 5760 MHz with Filter and Amplifier, A (Wade): Aug, 9
Dynamic Resistance in RF Design (Sabin): Sep, 13; Feedback: Dec, 29
Effect of Local Terrain on HF Launch Angles, The (Straw): Jul, 3; Feedback: Aug, 13
Effects of the Ionosphere (d'Avignon): Jan, 23
Electronic Antenna Switching (Hayward): May, 3
Filters (Makhinson): Jan, 3
G3UUR Method for Measuring Quartz Crystal Motional Parameters (sidebar): Jun, 20
Graphic Method for Calculating Z (Harwood): May, 13; Feedback: Nov, 12
High-Performance AGC System for Home-Brew Transceivers, A (Mandelkern): Oct, 12
High-Performance Antennas for 5760 MHz (Wade): Jan, 18
Homebrewing Black-Box Style (Duff): Nov, 13
Lumped-Element Directional Coupler (Sabin): Mar, 3
Measuring System Response with DSP (Bloom): Feb, 11

Microprocessor Controlled Multiband Transceiver, (Ahrens and Gray): Dec, 3
Modification of TVRO LNBs for 10 GHz (Wade and Twombly): Apr, 3
Modular, High-Performance 5.76-GHz Transverter, A (Healy): Mar, 13
More on Parabolic Dish Antennas (Wade): Dec, 14
PHEMT Preamp for 13 cm (Bertelsmeier): Oct, 7
PHEMT Preamp for 9 cm (Bertelsmeier): Dec, 23
PIC Based Repeater IDer, A (Sutcliffe): Oct, 3
Polyphase Network Calculation using a Vector Analysis Method (Yoshida): Jun, 9
Precision Two-Tone RF Generator for IMD Measurements, A (Rumley): Apr, 6
Refinements in Crystal Ladder Filter Design (Hayward): Jun, 16
Simple CW Demodulator for the DDC-Based Receiver, A (Anderson): Feb, 6
Simple Frequency Deviation Meter Using Time-Domain Techniques, A (Isley): Aug, 3; Feedback: Nov, 12
Spectral Measurements the Hard Way (Reed): Jul, 16
Termination Insensitive Amplifier, A (Makhinson): Jul, 21
Torque Capacity of Keyed Rotator Shafts (Leeson): Jun, 3; Feedback: Jul, 29
UHF+ VSWR Bridge, A (Wade): Feb, 3
Up to Four Receivers on a Single Antenna (Lass): Apr, 13
Using the Motorola DSP56002EVM for Amateur Radio DSP Projects (Forrer): Aug, 14
Variable IF Selectivity Unit, A (Thomson): Nov, 21

Miscellaneous

Conference Proceedings: Aug, 25; Oct, 26
Free SPICE Newsletter Previews New Simulation Techniques: May, 22

RF (Lau)

6-Meter Transverter Design: Sep, 24
10-GHz SMA to WR-90 Transition: Nov, 24
1296-MHz Cavity Preamplifier, A: Jan, 26

Calculating the Power Limit of Circuits with Toroids: Mar, 24
Designing VHF+ Yagis: May, 17
Running QRP in the ARRL and CQ VHF Contests: May, 20

Specialized Communications Techniques

HRPT The Easy Way (Emiliani, Righini and Rossini): Sep, 3
Measuring 9600-Baud Radio BER Performance (Bloom): Mar 16
Principles of HF Radio Direction Finding Loops, The (Brown): Sep, 19

Upcoming Technical Conferences

AMSAT Annual Meeting and Space Symposium, 1995: May, 21; Jun, 28; Jul, 29; Aug, 13
ARRL Digital Communications Conference, 1995: Mar 23; Apr, 12; May, 21; Jun, 28; Jul, 29; Aug, 13
Central States VHF Society Conference, 1995: Apr, 12; May, 21; Jun, 20
Central States VHF Society Conference, 1996: Nov, 12
Eastern VHF/UHF Society Conference, 1995: Jun, 28; Jul, 29
Microwave Update '95: Mar 23; Apr, 12; May, 21; Jun, 28; Jul, 29; Aug, 13
West Coast VHF/UHF Conference, 1995: Mar 23; Apr, 12

□□

Feedback

In the September issue of *QEX*, the article "Dynamic Resistance in RF Design," incorrectly stated that Fig 3 represented a triode vacuum tube. A better description would have been "beam power tube" or "pentode tube." These curves are also very similar to a bipolar or FET transistor. The figure does correctly illustrate the plate/collector dynamic resistance effect, which was the intention.—*Bill E. Sabin, W0IYH*

□□