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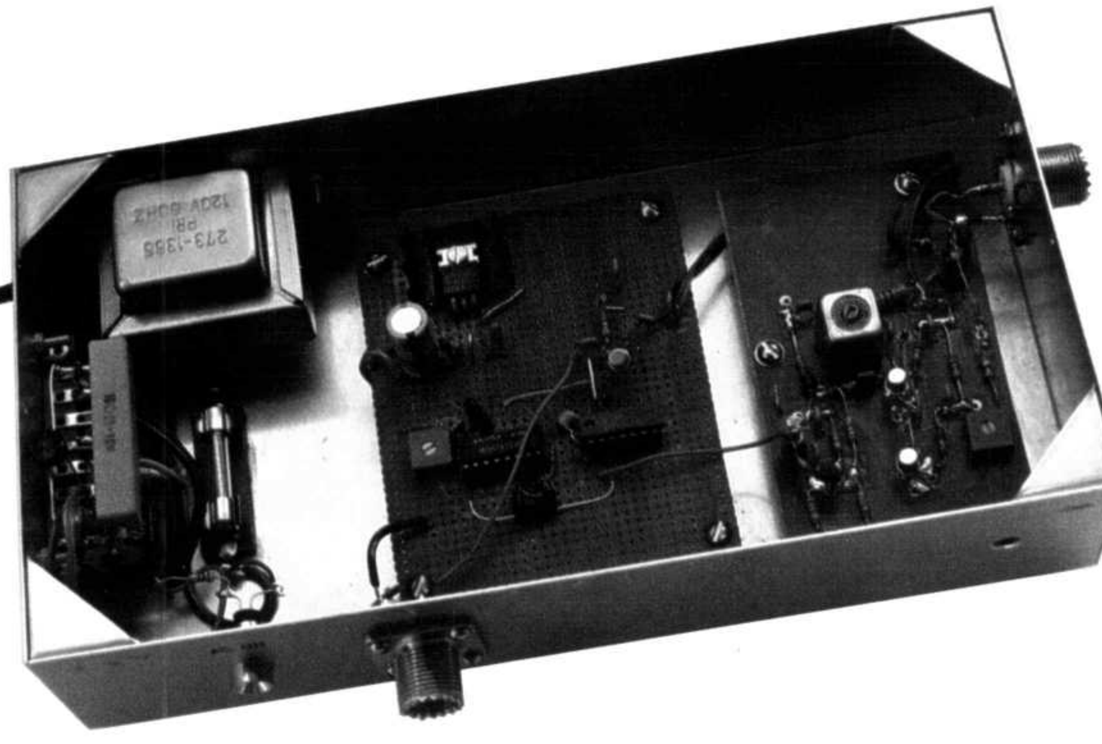

Extract Stable Clock Pulses From AM Broadcast Carriers

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It is common practice for VHFers/UHFers to stack two or more anntennas for increased gain, or combine two or more amplifiers for increased power. Learn how to use 1/4-wave power dividers as efficiently as 1/2-wave dividers. Also, here's the scoop on hybrid combiners—they're often used to combine amplifier stages, or are found in modulating and mixing circuits.

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By Geoff Krauss, WA2GFP

Many VHF+ records on Amateur Radio frequencies are achieved through the use of employer-donated equipment. Should these feats be recognized? Also, here's what state-of-the-art equipment amateurs are currently using on 50 MHz.

ABOUT THE COVER

The circuit for extracting stable clock signals for spread-spectrum applications. The board to the left includes a ferrite loop and a clipping amplifier. The board to the right consists of a synchronized oscillator, and the third board (center) converts that signal into a clock pulse.

Purposes of *QEX*:

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

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

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

Empirically Speaking. . .

On Emission Designators

Once upon a time, emission designators were simple. You had your A0, A1, A2, A3, A3A, A3J, A4, A5, F1, F2, F3, F4, F5 and your P. Fourteen! Maybe they were a bit much to learn for the beginner, but then the Novices had to learn only one: A1.

Ta dah! The World Administrative Radio Conference (WARC) of 1979 brought with it agreement on a new system of emission designators with 1296 combinations (like A1A and J3E) that even professional electronics engineers have trouble understanding. That's progress? Well, yes, from the viewpoint of pinpointing accurate technical descriptions of emissions; no, for the Amateur Radio Service. The problem is that the Amateur Radio Service is supposed to be an experimental service. One would think that hams should be able to try a new modulation technique on the air without applying to the Federal Communications Commission (FCC) for special temporary authority (STA) or a rule change. At present, chances are that you would need to ask for an STA, write a report, then request a rule change, all of which could spread over a year or two.

How did we get into this pickle? The final acts of WARC-79 were ratified by the United States Senate, then implemented by the FCC on January 1, 1985. Treaties are heavy-duty documents, so the Amateur Radio Service was not exempted from using these new emission designators, although some arguments were raised at the time. So, the FCC wrote the new emission designators into Part 97 of its rules.

It became apparent that some things were lost in the translation. At first blush, it looked like there were fairly good correspondences between the old and new emission designators, but that didn't hold up. After all, there were 14 old ones and 1296 new ones. The Southern California Repeater and Remote Base Association (SCRRBA) petitioned the FCC to allow F8E emission (frequency-modulated multiplex analog voice) on the new 902-MHz band, then again on all bands above 928 MHz. While the ARRL supported these changes in its comments to the FCC, we added a comment to the effect that G (phase modulation), 7 (digital mux), 9 (mixed digital/analog mux) and other types of information other than E (voice) could have been added. SCRRBA's F8E rule changes took the FCC more than six months. It became quite clear that similar requests for new emission symbols could tie up the FCC in unnecessary paperwork for years.

We toyed with the idea of using commonly understood English words and abbreviations such as voice, *image*, CW, RTTY, data, and so forth. In order to use such terminology in Part 97, it would be necessary to cross-reference them with the WARC-79 emission designators. After several iterations, we came up with a system that the FCC staff thought would be workable. In mid-1987, the timing seemed to be right as the FCC Private Radio Bureau had decided to try and rewrite Part 97 to reorganize it and make it shorter. So, an ARRL working paper entitled *Designation of Emissions in the Amateur Service* was written and published in August, 1987, to serve as a straw man. This 38-page working paper traces the history of emission designators, examines alternative methods of designating emissions, and proposes that emissions be designated by Specific English words and abbreviations. Single copies of the printed working paper may be obtained by sending a 9- × 12-inch SASE with $1.07 US postage to ARRL, 225 Main St, Newington, CT 06111, Attn: PR.—W4RI

Correspondence

The virtues of diversity reception on the HF bands have been known for decades, yet few amateurs are aware of the techniques involved, and even fewer have made practical use of them. Therefore, it is good to hear that some experimentation is taking place in this area, as reported in the article, "Experiments in Signal Improvement with Fractional-Wavelength Diversity Reception," by Douglas Kohl (Jul 1987 *QEX*, p 6). As welcome as this type of work is, however, I must say that I am extremely dubious about the conclusions arrived at in the article. Mr Kohl claims useful diversity gain can be obtained with an antenna spacing of only five feet, which amounts to about 0.04 to 0.09 λ at the frequencies he used (7-18 MHz). Research on space diversity dates back more than fifty years, yet I can find no references in the literature that indicate spacings anywhere near these values provide worthwhile diversity gain. For example, Henney's work states that the *minimum useful* antenna spacing at 7 MHz is 4 λ, fully two orders of magnitude greater than that used by Kohl.[1] While I'm sure that some decorrelation between the signals from two antennas is occasionally observable down to spacings of a small fraction of a wavelength, that does not prove that these spacings are useful. It has to be shown that the correlation coefficient is sufficiently small (less than about 0.6) if significant diversity gain is to be realized. The scale on the scatter plots in the article is not given, making them difficult to interpret, but I suspect that the scale is linear and may be exaggerating what is really a rather small amount of decorrelation. In addition, even if the decorrelation were significant in that particular instance, such circumstances (resulting from an unusually disturbed ionosphere) may be infrequent at best, and little or no diversity gain may be available under more typical conditions.

It is also not stated whether the plots represent samples from a single signal source, or whether samples from a number of sources in different directions have been merged. If the latter is the case, this would further invalidate the results, since the two antennas likely would have different directional properties because of mutual coupling between them and the effects of surrounding objects. A more convincing demonstration of the diversity system's efficacy would be to use it in a real application, such as a data transmission system, and show that a significant improvement in error rate is obtained.

The foregoing is not meant to denigrate Mr Kohl's work in any way, but simply to point out that attempting to apply his results to a practical situation will probably lead to disappointment. By all means, experiment with the technique, but be prepared to try much larger spacings! A more fruitful area for experimentation with very close spacing would be to use two antennas with opposite polarization, since this has already been demonstrated to provide diversity gain close to that which can be obtained with very wide spacing of identical antennas.[2]—*Barry McLarnon, VE3JF, 2696 Regina St, Ottawa, Ontario, K2B 6Y1, CANADA*

Notes

[1] Keith Henney, ed., *Radio Engineering Handbook*, 5th ed, McGraw-Hill, 1959, pp 19-118.

[2] G. L. Grisdale, J. G. Morris, and D. S. Palmer, "Fading of long-distance radio signals and a comparison of space- and polarization-diversity reception in the 6-18 Mc/s range," *Proceedings of the Institution of Electrical Engineers*, Vol 104, part B, pp 39-51, Jan 1957.

Bits

AMSAT Prepares for their Fifth Space Symposium

Amateur satellite enthusiasts are invited to attend AMSAT's fifth annual general meeting and space symposium in Southfield, MI on Saturday, November 7, 1987. Papers scheduled for presentation detail the operation of AMSAT-OSCAR 10, UoSAT-OSCARs 9/11, Fuji-OSCAR 12, Phase 3C, RUDAK, Phase 4, and the RS satellites. Exhibits and live demonstrations will be held, and Dr Tony England, WØORE, is the featured guest. The symposium will be held at the Southfield Hilton, in suburban Detroit, 35 minutes from Detroit's Metro Airport. For further information and registration forms, write to AMSAT, PO Box 1091, Ann Arbor, MI 48109-1091.

Hitachi Markets First CMOS Version of 6809 Microprocessor

Hitachi's HD6309 8-bit processor is the first complementary CMOS version of the industry standard 6809 8-bit microprocessor. Compared with other process technologies, the 6309 offers all the advantages of CMOS, including increased reliability, low power consumption, and reduced package size. The 6309 operates up to 3 MHz 50% faster than the previous NMOS version. It also provides a low power sleep mode that dissipates a maximum of only 15 mA.

Typical applications are data communication processors, hand-held terminals, portable instrumentation and Telecom equipment. Ten addressing modes are available, as well as two 8-bit accumulators that form one 16-bit accumulator for high-speed data handling and numeric processing.

The 63B90 (2.0 MHz) and 63C09 (3.0 MHz) versions come in a 40-pin plastic DIP, or a 44-pin plastic leaded chip carrier package. Cost: $8 for 100-piece quantities of the 63B09, and $9.60 for the 63C09 version. For further information, contact Hitachi America, Ltd, 2210 O'Toole Ave, San Jose, CA 95131, tel 408-435-8300.

Feedback

Author Micheals writes about corrections to his article, "Optimum Wire Size for RF Coils," (Aug 1987 *QEX*). In the fourth paragraph in column one on p 6, 0.001 inch should read 0.002 inch. Eliminate the "Q" in subheads two and three on the same page. In Eq 5 where the terms of the equation are defined, d_0, L, and D are expressed in the same units. The correct heading for Table 1 on p 7 is, "Factor A for Eq 5." And finally, Eq 6 should be

$$\frac{4 \times 0.551}{60}$$

—*Charles J. Michaels, W7XC, 13431 N 24th Ave, Phoenix, AZ 85029*

Midlatitude E_S at 220.1 MHz

By Michael R. Owen, W9IP/2
Geology Department
St Lawrence University
Canton, NY 13617

On 14 June, 1987, intense midlatitude sporadic E (E_S) was observed at 220.1 MHz by radio amateurs. This event represents the highest frequency at which E_S has been observed by amateurs.

The 220-MHz E_S event took place during an unusually intense and long-duration episode of propagation via E_S at 144.2 MHz (SSB). Beginning at 1456 UTC (14 June, 1987), William Duval, K5UGM, near Dallas, TX (see Appendix) began hearing numerous amateur stations across Florida, Georgia, and South Carolina via E_S on 144 MHz. During the subsequent 78 minutes, contact was established between station K5UGM and 14 other amateur stations in the Southeast on 144 MHz. Signal strengths were reported to be "extremely strong," peaking in the range of 1,000-10,000 μV.

Throughout the period, K5UGM requested stations to switch to the 220-MHz amateur allocation in an attempt to establish contact at that frequency. Beginning at 1210 UTC, John Moore, W5HUQ, near Jacksonville, FL (see Appendix) began test transmissions at 220.100 MHz. In addition, Al Ward, WB5LUA, and David Hallidy, KD5RO, (both near Dallas) were conducting test transmissions on 220.100 MHz.

During the period from 1510-1545 UTC, intermittent attempts were made to establish contact on 220.100 MHz. On several occasions, signals were heard at one or the other end of the Dallas-Jacksonville path. Weak signals, because of underdense ionization (scattering), were heard by W5HUQ on three occasions, and by K5UGM at several times during the period.

At 1544 UTC, signals were heard at both ends of the Dallas-Jacksonville path, and a brief communication link was established. Signal strength of W5HUQ, monitored in Dallas by K5UGM, was estimated at over 5,000 μV for a period of 1-2 minutes. Signal strength at both ends of the path strongly suggests that propagation was by overdense ionization.

The successful contact at 220.100 MHz between K5UGM and W5HUQ was monitored by another amateur station, KD5RO (Plano, TX near Dallas). Station WB5LUA (McKinney, TX north of Dallas), monitoring 220.100 throughout the period, did not hear W5HUQ although WB5LUA was heard in Florida by W5HUQ.

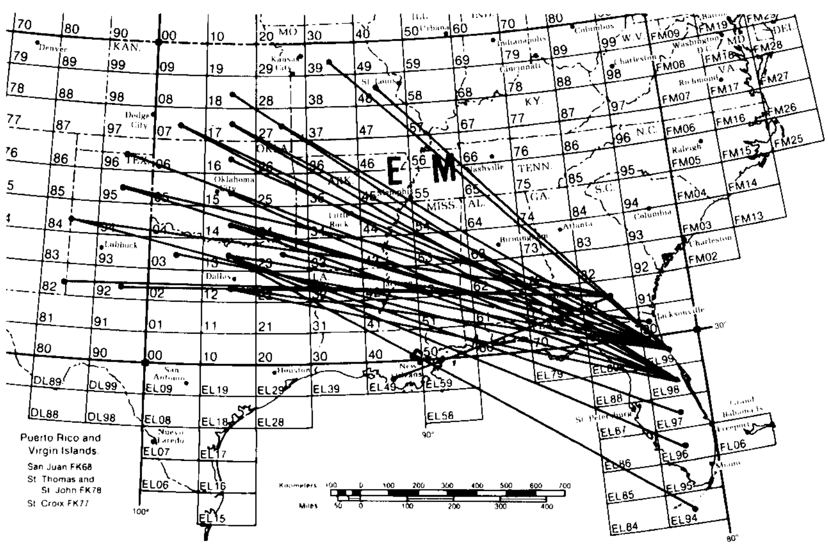

Fig 1—Paths covered during 1534-1554 UTC, June 14, 1987, on 144.2 MHz. (Squares are a latitude/longitude system of location used by radio amateurs.)

Detailed logs of the E_S event on 144 MHz were kept by several radio amateurs who were not involved in the 220-MHz event. These logs help to locate the position of E-layer ionization at the time ionization was sufficiently intense for 220-MHz reflection. Fig 1 was compiled by plotting the approximate paths covered by Amateur Radio communication via E_S on 144 MHz during the period that 220-MHz E_S propagation was observed. The time period covered extends from 1534-1554 UTC ($\pm$10 minutes from the 1544 UTC 220-MHz event).

The midpoints of most paths lay over the state of Mississippi during the time interval tabulated. By inspection of Fig 1, E_S ionization was probably confined to a patch about 300 km diameter, centered approximately 33° N, 90° W. Unfortunately, the center of intense ionization cannot be clearly defined because northeast-southwest paths, if possible, cannot be documented (one end would terminate in the Gulf of Mexico). There is no evidence of unusual path-shortening prior to or during the 220-MHz event; all plotted paths are in the range of 850-1300 miles. The shortest path, between southeast Georgia and New Orleans, probably utilized oblique reflection from the E-cloud.

Solar-terrestrial conditions during this period were generally quiet. The 10.7-cm radio flux at Ottawa was 78, a slight decrease from values of 80 the previous two days. At 1500 UTC, the geomagnetic field was passing from "unsettled" to "quiet" conditions. The Fredericksburg K-index was K=2 for the period 12-16 UTC (K=3 for the period 08-12); the planetary K-index was $K_p=2$ for the period. A-index values were 8 for Fredericksburg and 11 for planetary during 14 June. No unusual X-ray or proton fluence values were noted during the period. Four B-class X-ray flares were detected before 0900 UTC on 14 June.

Meteorological conditions in northeast Texas were turbulent, with intermittent thunderstorms and light rain. In northern Florida, the weather was clear. Along the path midpoint, the weather was generally clear as well.

(continued on page 9)

Extracting Stable Clock Signals From AM Broadcast Carriers for Amateur Spread-Spectrum Applications

By Andre Kesteloot, N4ICK
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McLean, VA 22101

This circuit provides jitter-free clock pulses by locking onto a readily available external reference signal source. Although it was designed primarily to provide clock pulses for Amateur Radio spread-spectrum transmissions, this circuit can also be used as a stable reference for frequency-calibration purposes.

Introduction

To recover data from spread-spectrum transmissions, it is necessary to reintroduce, at the receiver end, locally generated signals locked in frequency and phase to the clock used in the original transmissions. At carrier frequencies of up to 50 MHz, the extraction of clock pulses from direct-sequence (DS) spread-spectrum transmissions can be achieved fairly easily, using readily available ICs.[1] The 1986 FCC decision to relegate Amateur Radio spread-spectrum transmissions to frequencies above 400 MHz, however, singularly complicated the design and realization of this type of equipment.[2] Although it will be eventually possible to find a way to extract the clock signal at those frequencies, it is a major stumbling block to the development of uncomplicated amateur spread-spectrum equipment.

Another way to obtain a clock is to use an external reference signal readily available at both the transmitting and the receiving sites.[3] Since our amateur transmissions must take place at UHF, communications will usually occur when the two parties are within a fairly short distance of each other. Locally available reference signals are generated by TV, FM and AM radio stations. I have already explored the recovery of such signals, and have demonstrated the possibility of using vertical synchronization signals from local TV stations to generate reliable clock pulses for slow frequency-hopping spread-spectrum experiments.[4]

DS spread-spectrum on the other hand, requires that clock signals be in the megahertz region.[5,6] In DS, the clock drives a pseudorandom generator, which is modulo-2 added to the carrier, to vary the phase of the UHF carrier by 180 degrees. The carrier is cancelled and replaced by the familiar $[\sin x/x]^2$ spectrum (Fig 1). The ratio of F_c/F_k, where F_c is the RF carrier frequency (in our case $F_c > 400$ MHz), and F_k is the clock, is important. If F_k is low, the ratio is too high, and spreading of the signal does not take place. If F_k is too high, the RF signal is spread over too wide a bandwidth, and the spectrum used exceeds the limits of our amateur bands. In practice, for $F_c = 440$ MHz, an F_k between 500 kHz and 2 MHz appears reasonable. (In Fig 1, $F_c = 146$ MHz and $F_k = 1$ MHz. Nulls are clearly visible at $F_c \pm F_k$, $2F_k$, and so on, ie, 144, 145, 147, and 148 MHz. This experiment was conducted in a test load, and at power levels lower than 0 dBm.)

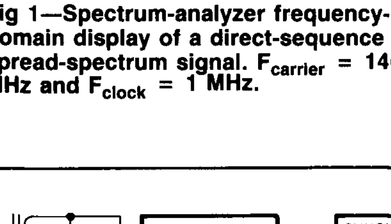


Fig 1—Spectrum-analyzer frequency-domain display of a direct-sequence spread-spectrum signal. $F_{carrier} = 146$ MHz and $F_{clock} = 1$ MHz.

Problems

There are many ways to generate clock signals. You could lock onto a TV station's video AM carrier, and divide down to obtain the required clock. The division process, however, introduces an ambiguity that has to be resolved at the receiving end, thus further complicating receiver design.

You can also extract horizontal TV sync pulses (at 15,750 Hz) and multiply that signal by 100 for a clock at 1.575 MHz. The problem here is that the multiplication process (using, for example, a 4046 phase-locked loop oscillating at 1.575 MHz and two cascaded 4017 divide-by-ten stages between the oscillator and the phase comparator) also multiplies the original jitter by 100! Some jitter is always present on the H sync pulse, and a jitter of 10 ns (10 ns = 0.01 µs), perfectly negligible at 15 kHz, becomes 1 µs at 1.5 MHz. This is clearly an unacceptable solution since the period of a 1.5-MHz signal is only 0.66 µs!

I followed a similar approach using the 19-kHz stereo subcarrier available from all FM stereo stations. Here again, jitter (principally because of incidental amplitude modulation and lack of operating-point stability in simple zero-crossing detectors) does not allow for a reasonably stable signal once the 19-kHz signal is multiplied by 100 to yield a 1.9-MHz clock.

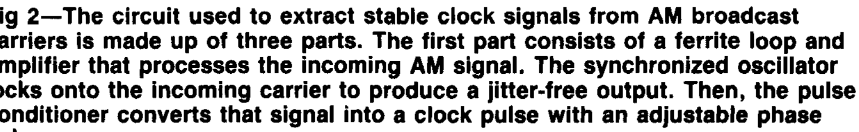


Fig 2—The circuit used to extract stable clock signals from AM broadcast carriers is made up of three parts. The first part consists of a ferrite loop and amplifier that processes the incoming AM signal. The synchronized oscillator locks onto the incoming carrier to produce a jitter-free output. Then, the pulse conditioner converts that signal into a clock pulse with an adjustable phase delay.

[1]Notes appear on page 9.

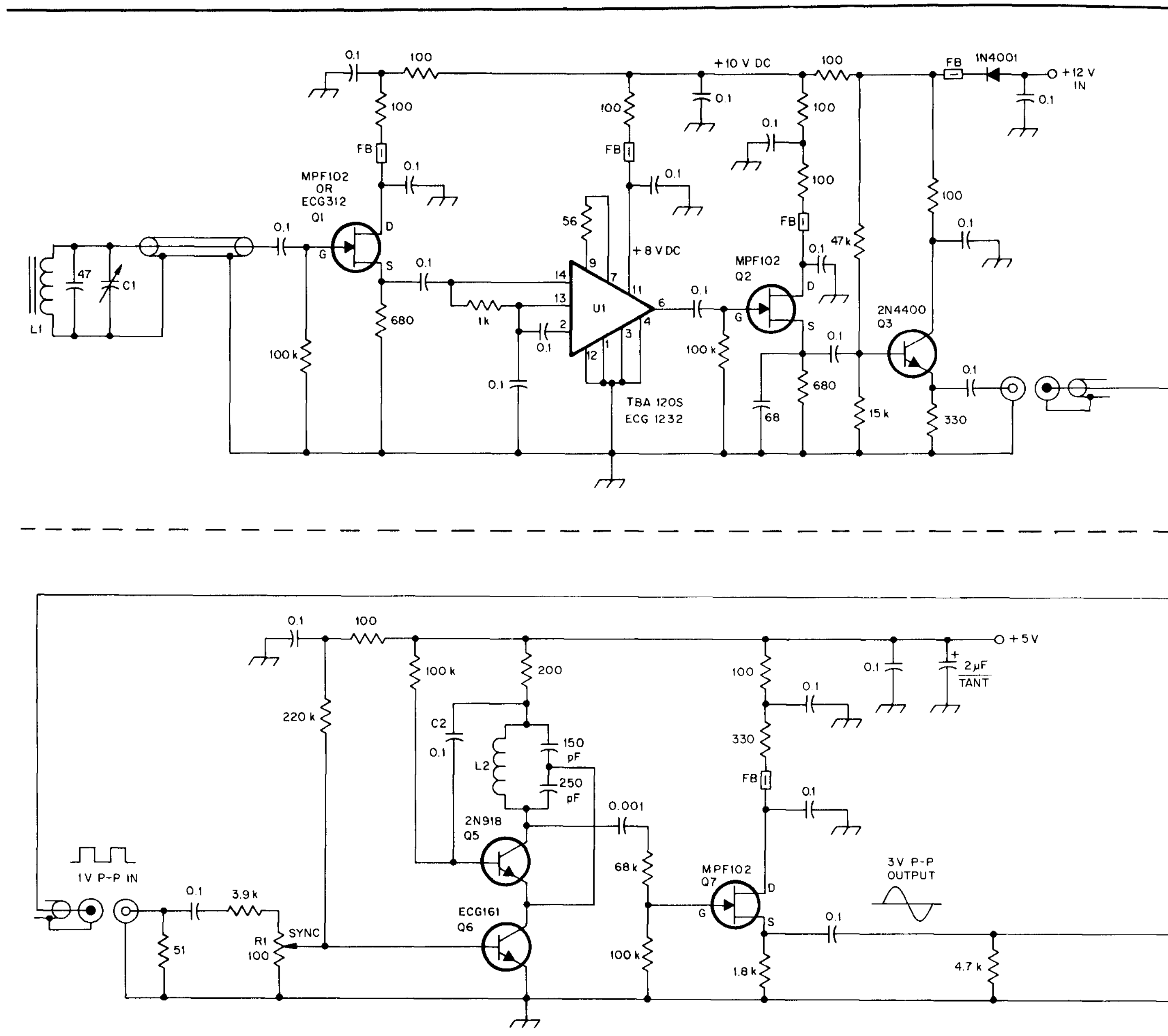


Fig 3—This circuit extracts stable clock signals from AM broadcast carriers for amateur spread-spectrum applications. All 0.1-µF capacitors in coupling and decoupling circuits are miniature 50-V polyester types. All capacitors smaller than 0.1-µF are silver mica.

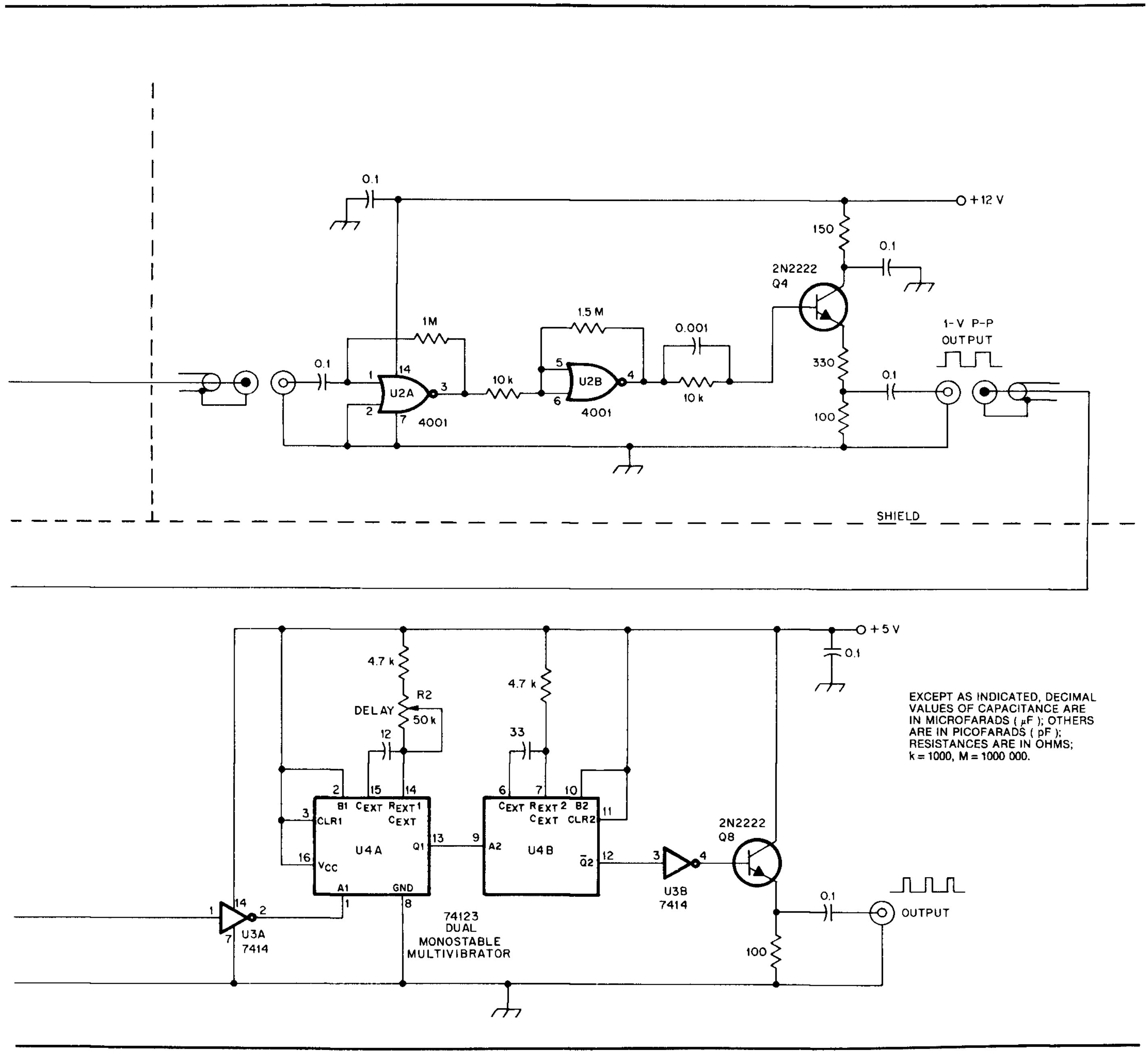
C1—Trimmer capacitor, 4-64 pF.
FB—Ferrite beads, Amidon FB-73-101.
L1—30 turns of 30-gauge wire, wound on an Amidon ferrite rod R-61-050-750.
L2—JW Miller shielded subminiature adjustable RF coil, catalog no. 9055, 60-120 µH.
Q1, Q2, Q7—MPF102 or ECG312 FET.
Q3—2N4400 (or 2N2222) NPN transistor.
Q4, Q8—2N2222 NPN transistor.
Q5—2N918 NPN transistor.
Q6—ECG161 NPN transistor.
R1—Adjustable potentiometer, 100 Ω.
R2—Adjustable potentiometer, 50 kΩ.
U1—TBA120S (Motorola) or ECG1292 (Sylvania) IF amplifier.
U2—CD4001 Quad NOR gate.
U3—7414 Hex Schmitt trigger.
U4—74123 Dual monostable.

I eventually decided to lock onto the carrier of an AM broadcast station, and after experimenting with different phase-locked loops, I settled for this design which uses readily available components. The circuit features a stable clock pulse, adjustable in phase to compensate for propagation delays, and it produces *no* measurable jitter.

The Circuit

Fig 2 shows the three parts of the circuit. The first part includes a ferrite loop and a clipping amplifier. The second part consists of a synchronized oscillator that locks onto the incoming carrier to produce a jitter-free output. Finally, the third part converts that signal into a clock pulse with adjustable phase delay.

Fig 3 shows the complete circuit diagram. The ferrite loop receives the



signal and U1, a TBA120S, amplifies it. U1 is an FM/IF 6-stage differential amplifier with good limiting and AM rejection properties.[7] Its output is amplified by U2A, a section of a CD4001 operated in its linear mode. The output is subsequently fed to U2B, connected as a Schmitt trigger. A 1-V P-P output is available at the emitter of Q4 (shown in the upper trace of Fig 7). This part of the circuit is the RF head (Fig 4). It can be positioned and oriented for best reception.

Fig 5 is the remote unit. It uses the 1-V P-P square wave from the RF head to lock the "synchronized oscillator."[8] The remote unit can be placed several hundred feet away from the RF head. This circuit, used for clock recovery in satellite installations, is yet generally unknown in Amateur Radio circles. Q5, Q6, and Q7 comprise the synchronized oscillator. Q5 functions as a modified Colpitts oscillator. It has two positive feedback paths, one from the common point between the two capacitors in the collector tank to its own emitter, and the other path from the junction of the 220-Ω resistor and the collector tank to the base of Q5, via C2. C2 is large and represents a very low impedance at the operating frequency. Q6 can be thought of as a dynamic emitter resistor for Q5. Since Q5 operates in class C, the conduction angle is very small. Each time conduction occurs in Q5, a voltage develops across Q6, and amplification of whatever signal is present at that time at the base of Q6 takes place. Conduction in Q6 is similar to the opening of a very brief "time window" during which synchronization to the input signal occurs. Because there is a tuned circuit in the collector of Q5, in the event of a temporary absence of sync pulses, the tank (functioning as a flywheel) continues to produce sine waves at a frequency close to the frequency of interest.

An AM input signal consists of a carrier (F_c = 1,390 kHz in our case), plus two sidebands ($F_c + F_{mod}$) and ($F_c - F_{mod}$). Assuming a single modulating frequency of 2 kHz, the input signal consists of three discrete RF frequencies—the carrier at

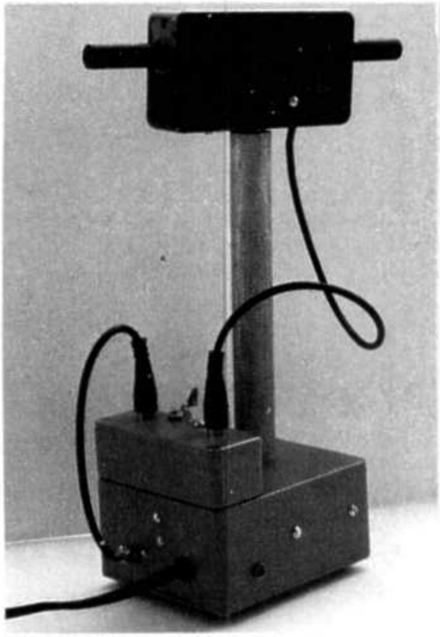


Fig 4—The upper part of the RF head swivels so it can be positioned for best reception. The smaller aluminum box houses U1 and associated components. U2 and the 12-V dc power supply reside in the larger box at the base.

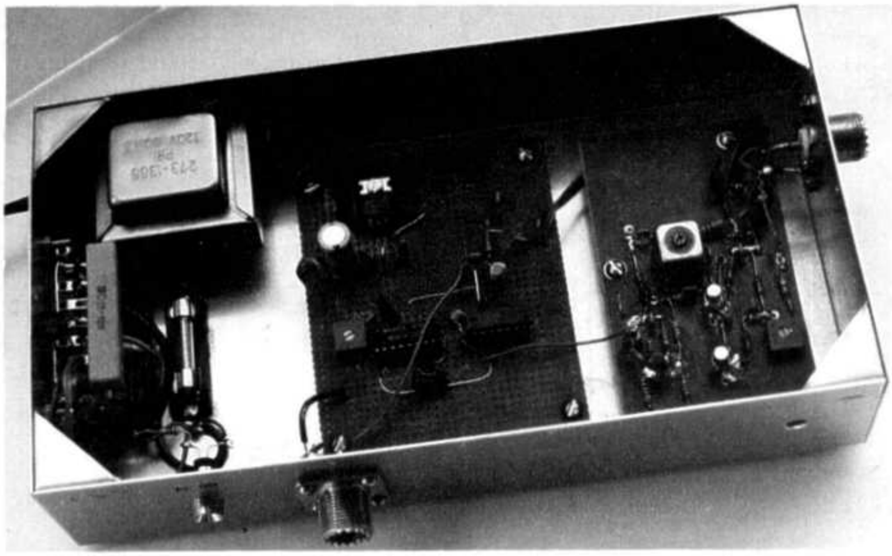


Fig 5—The remote unit. The board on the right supports the synchronized oscillator. The voltage regulator and the pulse-shaping circuitry are mounted on the center board.

1,390 kHz and the two sidebands at 1,388 and 1,392 kHz (Fig 6). In practice, the instantaneous frequencies and amplitudes of the two sidebands depend on the audio input and depth of modulation, respectively. These discrete frequencies in the RF spectrum are visible as jitter on the upper trace of Fig 7.

Although the frequency and amplitude of the sidebands vary continuously, the mentioned attributes of the carrier are constant. Because of the flywheel effect, the synchronized oscillator, operating as a sort of coherent amplifier, tends to accept the carrier as the sync information. Jitter on the input signal tends to be perceived as an aberration, and is essentially ignored. Hence, the output sine wave at the collector of Q5 does not exhibit input jitter.

Finally, Q5's output is buffered by Q7, an FET stage. With the output of a synchronized oscillator being constant in amplitude throughout the synchronized range, it is acceptable to feed that output to U3A, a 7414 Schmitt trigger to obtain a stable trigger pulse. That pulse is then fed to the first of two monostable oscillators connected in series. The first portion of U4, a 74123, introduces a variable delay, adjustable by means of R2, over a range of approximately 270 degrees. U4B, the second monostable, outputs a short positive-going clock pulse, with Q8 connected as a 50-Ω line driver.

Fig 7's upper trace is the leading edge of the input signal to the synchronized oscillator, available at the top of R1. Peak jitter covers about one division, or approximately 0.02 μs. (In practice, average jitter is about 0.01 μs. This is consistent with an upper audio modulation frequency of 10 kHz. The peak jitter displayed in Fig 7 is probably the resultant of several causes, including some incident phase modulation.) The lower trace shows the signal at the emitter of Q8. There is *no* visible jitter at the output, so we know that the synchronized oscillator is operating properly. (Jitter on the upper trace is essentially caused by residual amplitude modulation.)

Construction

Observe good RF construction practices when building the synchronized oscillator, particularly with respect to ground returns and shielding. The prototype of my oscillator is built on fiberglass circuit board, using self-adhesive silvered circuit decals for connection points.

Because of U1's sensitivity, I recommend that it be housed in a separate enclosure from that of the synchronized oscillator. The synchronized oscillator produces several volts of RF at the same frequency as that of the input of U1.

The portion of the circuit comprising Q1, Q2, Q3 and U1 is housed in a small (¼ × ½ × 3½ inches) aluminum die-cast box. U2 and Q4 are mounted in a larger (2¼ × 3½ × 4½ inches) box used for the base of the receiving head. The loopstick is mounted in a plastic box that swivels on a wooden dowel and is positioned for best reception. In my present installation, the receiving head is located near a window so I can orient the ferrite loop for maximum signal reception. The receiving head connects to the synchronized oscillator with 25 feet of RG58 coax cable, with no visible degradation. You could easily use 100 feet of cable, if required. The larger aluminum box also

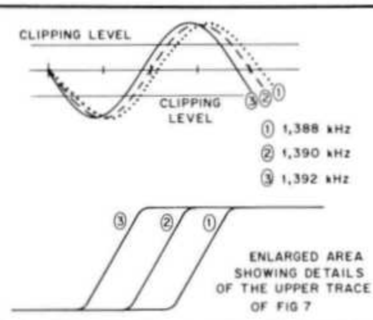


Fig 6—A simplified time-domain representation of amplitude modulation (see text).

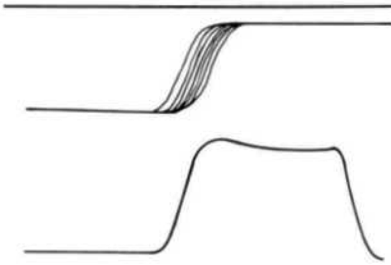


Fig 7—The upper trace shows the input signal going to the synchronized oscillator, and the lower trace is the signal at the emitter of Q8. The vertical scale is 1/div; the horizontal scale is 0.02 μs/div.

contains a 12 V dc power supply (not shown on the schematic) for the receiving head. A separate aluminum box (2 × 5 × 9½ inches) houses the synchronized oscillator, the pulse conditioner elements, and a 5 V dc power supply (see Fig 5).

Adjustments

An oscilloscope and a frequency counter are required to adjust this unit. (I locked onto WMZQ, a Northern Virginia radio station that uses a solid-state transmitter to broadcast on 1,390 kHz.) Connect the oscilloscope probe at pin 14 of U1, and the frequency counter probe at the emitter of Q4. The counter will indicate the carrier frequency of the AM broadcast transmitter you are receiving. The counter will probably jump ±100 Hz around the carrier frequency, representing modulation peaks (this reading depends on the integration time of your counter). On the scope screen, adjust C1, the trimmer across the loopstick coil, for maximum signal amplitude of the carrier you are trying to lock onto. By moving the scope probe to the emitter of Q3, you should see a fairly clean looking 150 mV P-P square wave. Look for a similar signal, 4 V P-P in amplitude, at the emitter of Q4.

In the remote unit, connect the oscilloscope probe to the source of Q7 (*not* to the tank of Q5). Adjust the slug in the collector tank of Q5 to produce a free-running frequency close to that of the AM broadcast station you are locking onto. This adjustment must be made with R1's wiper turned to ground potential. If you have a dual-trace triggered sweep oscilloscope, connect the synchronized channel to the source of Q7 (oscillator output), and the other channel to the input pulse. As the input signal applied to Q6 is slowly increased by adjusting R1, you should see the input pulse lock onto the sine wave (it is actually the sine wave that locks onto the input pulse). Jitter should be visible on the input signal only. (If the oscilloscope were synchronized on the jittery input signal, both the input *and* the output signal would appear to jitter.) Increasing the input level setting can "oversynchronize" the oscillator and possibly drive it into an "injection-oscillator" mode.[9] This results in distortion at the output, and possibly jitter, as the tracking range of the circuit increases.[10] Keep the input signal as low as possible.

Your frequency counter, now connected to the emitter of Q8, should indicate the carrier frequency you are locking onto, with a maximum deviation of ±1 Hz. This deviation represents the least significant digit resolution of your counter, and not a loss of synchronization.

Conclusion

In my synchronized oscillator, a 2N918 transistor was chosen for Q5 because of its good RF properties. An ECG161 was selected for Q6 because of its low noise. If you are only interested in breadboarding a synchronized oscillator for experimental purposes, you may use 2N2222s or 2N4400s in both positions. The result is some degradation of performance. Depending on the type of transistor used, the value of the 220-kΩ bias resistor is adjusted so that Q5's emitter is at about $V_{cc}/2$.

This circuit provides extremely accurate clock signals and uses readily available parts. Whether you are interested in spread-spectrum applications or another phase of Amateur Radio, build a synchronized oscillator, and experiment with this very versatile building block. It can also be used as a divider or multiplier.

Acknowledgements

I thank Mr V. Uzunoglu for devoting his time to discuss with me some of the properties of the synchronized oscillator.

Notes

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[7]*Linear and Interface Integrated Circuits*, Motorola, Inc, Phoenix, AZ 1985, p 6-142.
[8]V. Uzunoglu and M. White, "The Synchronous Oscillator: A Synchronization and Tracking Network," *IEEE Journal of Solid State Circuits*, Vol SC-30, No. 6, Dec 1985, pp 1214-1224.
[9]V. Uzunoglu, private communication, May 15, 1987.
[10]V. Uzunoglu and M. White, "Some Important Properties of Synchronous Oscillators," *Proceedings of the IEEE*, Vol 74, No. 3, Mar 1986, pp 516-518.

Midlatitude Es at 220.1 MHz

(continued from page 4)

It is apparent that neither geomagnetic disturbances nor intense thunderstorm activity played a major role in this occurrence of Es.

Appendix

Station Parameters

Station:	W5HUG	K5UGM
Operator:	John Moore	William Duval
Location:	548 Clermont Ave	2316 Spanish Trail
City:	Orange Park, FL	Irving, TX 75060
Latitude:	30°, 06', 15" N	32°, 46', 15" N
Longitude:	81°, 27', 30" W	96°, 57', 30" W

Path distance: 1497 km (931 miles)
Frequency: 220.100 MHz

Equipment

Transmitter Power:	20 W	600 W
Antenna Gain:	14 dBd	14 dBd
Antenna Height:	21 m	10 m
Feed Line Loss:	1.8 dB	0.5 dB
Receiver Noise Figure:	0.5 dB	0.3 dB

Bits

Fiber Optic Courses Available on Videotape

The Texas A & M University is proud to announce the availability of two new videotaped courses about fiber optics. The first tape, *Overview of Fiber Optic Technology,* is a telecommunication video training tape addressing the principles and characteristics of fiber optics. *Methods of Fiber Optic Splicing* describes the preparation and methods of fiber optic splicing. This high-quality tape presents information in an easy-to-understand, applications-oriented format. Each tape costs $395, and can be purchased in VHS or Beta format.

Using videotapes as an instructional tool is economical and cost-effective. Tapes are reusable and can be viewed by an individual or a group for initial training or refresher sessions. For further information on purchasing the fiber optic videotapes, contact OTM Engineering, Inc, Suite 205, 4005 Manchaca, Austin, TX 78704, TX residents call 512-462-2552, or, from all other locations, phone 800-426-2552.

Interface Circuits Data Book Available

The Linear Products Division of Texas Instruments has combined four separate publications to produce a new 1420-page book, *The Interface Circuits Data Book*. This volume covers the entire spectrum of interface products from classic line drivers and receivers through speech synthesis devices. Its seven chapters and three appendices contain a complete description of the products listed. For information on how to obtain a copy, contact Texas Instruments, Inc, PO Box 809066, Dallas, TX 75380.

By Bill Olson, W3HQT
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Burnham, ME 04922

Power Dividers and Combiners

At VHF and UHF, it seems that we are often stacking two or more antennas for increased gain or combining two or more power amplifiers for increased power. This month, we'll take a look at different methods for making power splitters and combiners.

Reactive Power Dividers

We are all familiar with combining or "stacking" antennas for increased gain. The trick is to feed each of the antennas in the array with signals of equal amplitude that are in phase. The device that performs this function is a *power divider* or *power splitter.* For combining antennas, the most common power divider is a ¼-wavelength matching transformer made from coaxial line (this is also called a *Q section*). Some amateurs prefer ½-wavelength dividers; these are nothing more than two ¼-wave units back-to-back. See Fig 1.

The idea here is that you combine two or four (or five, six or nine) antennas in parallel and then use a matching transformer to get you back to 50 ohms. The matching transformer is a length of transmission line of an impedance (Z_0) that will match the impedance of the main feed line (Z_1) to the impedance of the paralleled antennas (Z_2). The impedance of the Q section can be calculated from

$$Z_0 = \sqrt{Z_1 Z_2} \quad \text{(Eq 1)}$$

The matching transformer must be an odd multiple of a quarter wavelength long.

To handle reasonable transmitter power with low loss, power dividers for antenna arrays are usually built as coaxial air lines and made from heavy duty materials. I like to use 1-in-square aluminum tubing with 1/8-in wall thickness for the outer wall. Round brass or copper tubing works well for the inner conductor. A type-N female chassis-mount connector will fit nicely on the 1-in-square stock, simplifying construction. See Fig 2. The finished unit can be waterproofed easily, is compact and is low in loss. A power divider is used to match a 50-ohm source to multiple 50-ohm loads, so the phasing lines that run from the divider to the antennas need only be equal lengths of 50-ohm coaxial cable.

People often ask if the ½-wave power divider is better than the ¼-wave design. While there are possible mechanical advantages to ½-wave dividers (shorter phasing lines for one), it has been my experience that the ¼-wave divider works equally well if the antennas are all the same and have good 50-ohm matches. I find ¼-wave dividers easier to build.

It is a common belief that ¼-wave dividers work poorly because the SWR looking into any one of the output ports is very high. This is true. If you terminate the input port and all but one of the output ports with 50-ohm loads, the SWR at the unterminated port will be quite high—around 7:1 in the case of a 4-way divider. So . . . you might suspect that *all* the received energy would be reflected back out the antenna into space again and very little would get to the receiver. This does not seem to happen in real life. Why not?

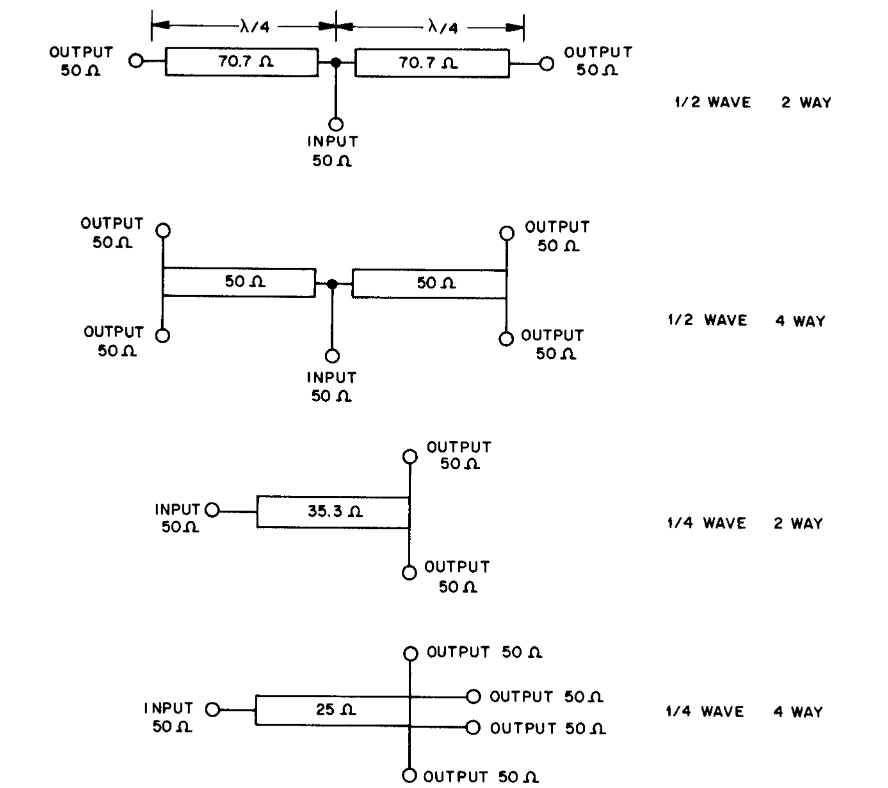

Fig 1—Reactive power dividers.

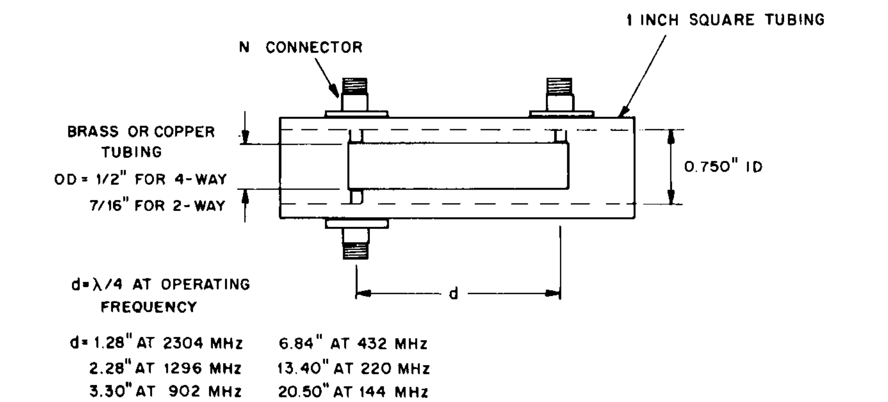

Fig 2—Construction details of a ¼-wave, 2-way power divider.

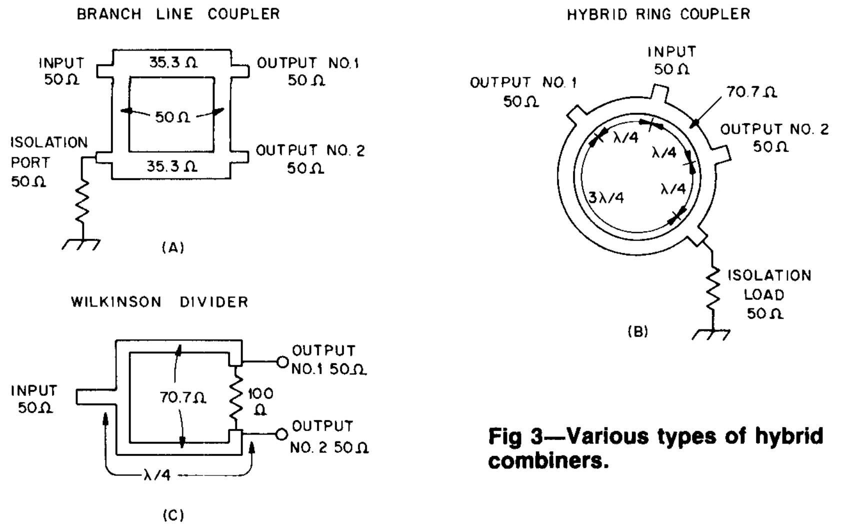

Fig 3—Various types of hybrid combiners.

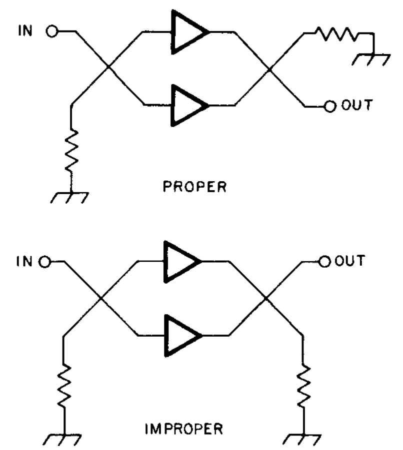

Fig 4—Combining two amplifiers using hybrid combiners. The combiners must be arranged so that the output signals are in phase.

Because in real life, all four output ports are excited by equal in-phase signals. As long as the loads are matched and the phasing lines are correct, the ¼-wave divider will work properly.

Hybrid Combiners

Those who read the 23-cm linear amplifier construction article in my June 1987 *QEX* column are familiar with power combiners made from Sage Wireline®The Wireline combiner is just one type of *hybrid combiner*. Unlike reactive power combiners, hybrid combiners have isolation between output ports. An *isolation load* incorporated in the design absorbs some of the reflected energy. Hybrid combiners are most often used to combine amplifier stages, or in modulating and mixing circuits.

While hybrid combiners can be found in many division factors, the most common is the 2-way, 3-dB combiner. Four-way division and recombination is accomplished by two stages of 2-way combining. The 3-dB versions come in three- and four-port types. Sage Wireline is a four-port hybrid—the fourth port is where the 50-ohm isolation load resistor is connected. Branch-line couplers and hybrid-ring couplers are other types of four-port, 3-dB hybrids, while the popular Wilkinson hybrid is a three-port device with a "floating" isolation resistor. See Fig 3.

Note that the branch line coupler, Sage Wireline couplers and one version of the hybrid ring coupler are all *quadrature hybrids*. The two outputs are 90 degrees out of phase. When combining amplifier stages using quadrature combiners, care must be taken to assure the final recombination is in phase (adding), rather than 180 degrees out of phase (canceling). See Fig 4.

Hybrid combiners are often seen in microstripline circuits, but they can be built from coaxial line of the proper impedance or in air-dielectric stripline for high power combining. While the isolation resistor dissipates no power if the loads are perfectly balanced, it could have to dissipate half of the input power during tune up or if one side of the amplifier fails for some reason. Therefore, the isolation port is often routed off the circuit board to a jack where a high-power load can be connected. Your homework assignment is to design a pair of hybrid combiners for combining two 250-W, 1296-MHz tube-type amplifiers. If that seems too easy, how about combining four amplifiers. . .

Sage Labs to the Rescue

In my June >50 column, I mentioned that the Sage Wireline is difficult to come by. I have some good news. It seems that the people at Sage Laboratories also read *QEX* and have very generously offered us a deal we can't refuse: *free* Wireline! We received some correspondence from Theodore Saad, President of Sage. He points out that while Wireline is not an expensive product, there are minimum orders (which might put Wireline out of reach for the experimenter who needs only a few inches). Mr. Saad explains that Sage has some BJC Wireline that is slightly out of spec but perfect for use in amateur applications such as the 23-cm power amplifier. Sage is willing to make samples of this Wireline available to hams! To avail yourself of this offer, simply write to Peter Alfano, Marketing Assistant to Vice President of Sales, c/o Sage Laboratories, Inc, 11 Huron Drive, Natick, MA 01760-1314. Explain briefly what you will do with the Wireline and ask for a length at least one inch longer than calculated to allow for cutting and trimming (no 1.8-MHz combiners here, okay?). Be sure to mention you read about it in *QEX*.

VHF and Microwave Conference Proceedings

Many of you probably have attended some of the VHF and microwave conferences held each year. The Central States VHF Society puts on a whizbanger, as does the West Coast VHF/UHF Society, the Northeast VHF Society and the Pack Rats. Don Hilliard, WØPW, also sponsors the Microwave Update each year in Estes Park, CO. These conferences are a wealth of practical information for the serious VHF/UHF/SHF enthusiast.

Proceedings of these conferences are coveted by many and have been hard to get. This year, however, proceedings of the Central States VHF Conference and Microwave Update '87 have been published by the ARRL. The League is making the proceedings of these conferences available to all for $10 each, plus $2.50 for shipping and handling. As this is being written, they are also working on proceedings of the Mid-Atlantic States (Pack Rats) VHF Conference. These proceedings are a great way to find out what hams around the country are doing on VHF and above.

Papers presented in the *Proceedings of the 21st Conference of the Central States VHF Society* (166 pages) include topics as diverse as:

- 2 to 6 GHz power amplifiers (WØPW)
- a no-tuning crystal-controlled microwave LO (KK7B)
- meteor scatter propagation (W9IP)
- use of small TVRO dishes on EME (VE4MA)
- solid state power amp for 5.7 GHz (WA5TNY)
- GaAsFET mixers for 5.7 GHz (W7CNK)

(continued on page 13)

VHF$^+$ Technology

By Geoff Krauss, WA2GFP
16 Riviera Drive
Latham, NY 12110

After an absence of over eight months, it is a good feeling to rejuvenate this column. Repairs caused by an attic fire accounted for most of my time. While replacing the kitchen (the weight of the water pumped into the attic caved in the ceiling), I had time to contemplate reader questions. One common query is: "*QEX* appears to only print articles related to digital experimentation." Show your fellow VHF+ers a copy of *QEX*: The basis of any magazine is the items that readers submit. With a column such as this, I try to include everything furnished to me by you. When the reader files are depleted, I dig into my material that I feel will be of interest to you. If you'd like more VHF+, then *write*.

I am interested in articles about the equipment recently used for the first successful EME contacts on 3456 and 5760 MHz. And what about information on the rigs used to set new North American DX records on 5.76, 24 or 48 GHz? Yes, there are *QST* columns to cover operating news, but technical details are often not presented to the depth desirable by VHF+ers.

VUCC on 48 GHz?

The W2SZ/1 contest group worked five stations on 24 GHz in the June 1986 ARRL VHF QSO contest. Soon after, the VUCC rules were upgraded to offer an award for contacts with five different grids on 24 GHz. At the same time, the awards committee added an award for 48-GHz contacts with at least five different 2° × 1° grids. The first application may be long in coming. The present worldwide DX record on 48 GHz is 33 miles (HB9AMH and HB9MIN in 1984).

A quick look at my auto map shows that 1 degree of longitude equals 58 US miles. While it is no challenge to work four grid squares (set up at a four-square corner and work the four corners at short distances!), the fifth grid may require world-record performance. The acquisition and preparation of 48-GHz equipment is difficult enough without a psychological handicap of five grid VUCC; VHF+ers should be provided with an award to promote realistic 48-GHz operation. If five grids are hard to obtain and four are too easy, then the answer is five half grids. That is, divide each grid into eight subgrids, each ½° × ½° and of about 25 miles per side. The first four half grids remain easy to work for anyone with the right equipment. The fifth half grid will require a contact over a minimum distance of at least 13 miles.

Equipment Accessibility

Another subject is the acquisition and use of *special* equipment. Special equipment is defined as any unit or part thereof that is either not owned by an amateur, or was acquired in a manner that would preclude others from obtaining the same or a similar item. Consider the following: One VHF+er has access, through his employer, to a high-power TWT amplifier; another can use a computer-guided, radome-housed 30-foot dish stationed at his company. Is use of either a truly amateur endeavor?

Just as there is a separate class for commercial equipment in some contests (the ARRL EME contest), there should be special notice taken when an amateur VHF+ feat is first accomplished with equipment not commercially available. One way to check equipment is by technical disclosures of the gear used. The recent 48-GHz SSB work of Tom Hall, WA3RMX, and Lynn Hurd, WB7UNU/W7TYR is one example. The equipment was freely exhibited; it was shown that the gear was assembled with bits and pieces available at hamfests and flea markets. Some of the first EME successes were accomplished with larger commercially-owned antennas or special high-power klystrons furnished by a manufacturer, government agency, or the like. Other VHF+ers had no chance to obtain similar units! Should the result, while proving it can be done, be recognized or go into record books as an *amateur* first? What effect, if any, does this have on increasing VHF+ activity? Your comments are invited.

State-of-the-Art Equipment

I've often referred to some equipment as state of the art. Some of you have asked, "What *is* the state-of-the-art on this or that band, anyway"? I've compiled a series of columns on what I believe amateur state-of-the-art technology to be, as of mid-1987. Any correspondence to add or to change the following descriptions are welcome.

To many experienced RF designers, 50 MHz is almost HF. The halcyon days of 6-m AM are gone; although there is a frequency range set aside for AM, I have not heard an AM station in years. Many SSB stations get on in the late spring and early summer, when E-skip is most likely to occur, and contacts over several thousand miles are possible. CW use between 50.0-50.1 MHz (and sometimes 52+ MHz NBFM work) is not rare, especially for different scatter modes (including aurora). Whether we talk about separate transmitters and receivers or transceivers, the frequency is low enough so that PC board construction techniques are used.

Transmitters are occasionally part of a dedicated 50-MHz SSB/CW transceiver. Most often, transverters are used to heterodyne an intermediate frequency (IF) up to 50 MHz. Simplex USB operation is almost always used (ie, both stations are on the same sideband, the same frequency, and alternating transmissions). The criteria for an IF, therefore, is nominally 10% of the final frequency, and an IF near 50/10 = 5 MHz should ideally be used. The nearest ham band at 7.0-7.3 MHz should not be used, as powerful commerical stations reside in the 40-m band with strong signals that can overload the IF stage of many receivers. A 20-m IF is also affected by other hams transmitting close by. Other nuisances can be classified as (1) Most 7-MHz SSB operation is on LSB. Sideband inversion is more difficult. (2) Without a complex LO switching system, the fairly narrow 7-MHz band does not allow much 50.0-54.0 MHz band coverage. (3) Filtering of the IF and heterodyne LO signals is easier if a higher IF is used. See Table 1. The last two combinations of Table 1 offers several advantages, especially in image filtering.

The amount of output power generated by a 50-MHz SSB/CW signal is limited only by the equipment used. While few of the 2- to 30-MHz power amplifier arrangements (such as 4, 6, or 8 paralleled TV-sweep tubes) are easily adaptable to 6 m, most one and two tube circuits are usable. Many final tubes (8877, 4-1000A, or a pair of 3-500Zs) are easily capable of delivering maximum legal output power (1500 W). True amateur state of the art, here, is centered on two things: (1) Increasing the linearity of the linear amplifier to reduce intermodulation (IMD) products; (2) The use of a set of several RF power FETs (field-effect transistors) to provide significant power levels, while still maintaining decent linearity. With respect to item 1, any operator who has participated in a VHF contest when several dozen higher-powered stations sit within a few kHz of each other knows that low linearity/high IMD is a pox on one's fellow operators. If you do not understand why this happens, or how to measure two-tone IMD, refer to *The ARRL Handbook*. In some contests, I've measured so-called linears at less than −23 dB IMD, with respect to each tone of a two-tone carrier. Good numbers here should be in excess of −30 dB. For a tube PA, a good IMD is in the range of −36 to −47 dB.

Considering item 2, high-powered amplifiers with more than 2 kW of output power, and better than −35 dB IMD by use of heavy ALC feedback, have been built using several devices such as Motorola's MRF154 (a quad of paralleled dies for the MRF150 FET). The MRF154 is good for 600-700 W output at 50 MHz, with 50-60 V dc on the device drain. (This makes the potentially lethal 2-4 kV HV dc supply, associated with power tubes, unnecessary.) Techniques for properly combining four parallel stages, each with a very low-output impedance, to a standard 50-ohm impedance, are now available (see US Patent 4,647,868, available from The Commissioner of Patents, Washington DC 20231 for $1.50).

Receivers are usually down-converters placed in front of an HF receiver/transceiver to act as an IF strip. External noise is less at 50 MHz than at HF, so a lower total receiver noise figure (NF) can be of practical value. NFs lower than 1 dB are useful, particularly as there is less degradation if the antenna impedance changes. A good GaAsFET RF stage not only provides a stage NF as low as 0.25 dB (a Fujitsu FSC10LF device with an oversized coil in the input network), but also has more than enough gain to overcome the loss of a subsequent double-balanced mixer (DBM). A large dynamic range is required for a 50-MHz receiver used for contest or weak-signal work. Thus, a high IP_3 (third-order intercept point) is desirable; a higher IP_3 point is achievable with a GaAsFET than with a bipolar device, and sufficiently high IP_3 in a DBM can be provided using newer matched FET quads (Siliconix Si8901). A current practice places a narrow crystal filter as far forward as possible in the receive converter, to restrict IMD-causing heterodynes created by large-amplitude signals that are close to, but not exactly at, your receive frequency. Thus, if you are listening at $F_0 = 50.110$ and there are powerful stations at $F_1 = 50.115$ and $F_2 = 50.120$, your mixer may generate the undesired third-order product $P = 2 \times F_1 - F_2 = F_0$! If the amplitude of both signals at F_1 and F_2 is attenuated by several tens of decibels, as by placing before the mixer a crystal filter with a narrow bandpass (50.1098 − 50.1123 MHz), the IMD level can be sharply reduced. Since the crystal filter is not tunable, you must receive at exactly 50.110. Perhaps this explains why some stations do not stray from a particular frequency during an entire contest.

Table 1

IF Band Coverage Versus Image Frequency Filtering

IF Band	*LO Freq*	*Band Coverage*	*Image Freq*
7.0- 7.3 MHz	57.3 MHz	50.3-50.0 MHz	64.3-64.0 MHz
14.0-14.3 MHz	36.0 MHz	50.0-50.3 MHz	22.0-21.7 MHz
21.0-21.4 MHz	29.0 MHz	50.0-50.4 MHz	8.0- 7.6 MHz
28.0-29.7 MHz	22.0 MHz	50.0-51.7 MHz	6.0- 7.7 MHz

Unlike higher VHF+ bands, the optimized NBS designs (Yagi-type horizontally polarized beams) have been fairly slow to show up on 50 MHz. This may be because the length of all but the shortest NBS Yagi is larger than most 6-m stations want to handle. Nevertheless, a number of 6-12 element beams have been designed, built and tested. W2SZ/1 regularly uses a vertically stacked pair of 11-element monsters, with the lower beam fixed in a selected direction and the upper beam fully rotatable. A set of coaxial switches and cables allows selection of upper, lower or both beams. Jay Rusgrove, W1VD, has a set of four smaller beams stacked one above the other on a vertical mast, offset from the side of his tower. A rotator at one end of the mast, and a bearing at the other, allows the mast to turn the beams over a range of about 300 degrees. The direction to which the beams cannot turn is chosen by selecting the side of the tower to which the mast hold-off brackets are attached. The switching system allows one, two, or all four beams to be combined for operation.

My next column will discuss traveling-wave tubes—what they are and how they work. See you then.

>50

(continued from page 11)

The *Proceedings of Microwave Update '87* (136 pages) include:

- practical solid state transverters for 2.3 and 3.4 GHz (KK7B)
- modifying the UPX-6 cavity for 902 MHz (VE3CRU)
- stripline filters for microwave frequencies (WA8NLC)
- a 3312 MHz LO (WØPW)
- transverter and power amp for 3456 MHz (KØKE)
- 13 cm power amplifier using the 2C39 (VE4MA)

I've just covered a few of the excellent papers in these proceedings. Plans for the Mid-Atlantic States proceedings include articles on a two-tube 2C39 amplifier for 902 MHz and lots of solid-state projects for 902 MHz and up.

New Address

Next month there'll probably be a new address on the byline, since I'm moving another seven miles down east. Keep those cards and letters coming—the post office knows where to find me!

Bits

From Schematic to PC Board

Looking for a professional service to manufacture a PC board for your one-of-a-kind project? Midland Technologies can accommodate you or your small organization. The staff at Midland will quote you prices on any of their services ranging from prototype PC boards, using your artwork, to complete turn-key assemblies. For a free price and facilities list, contact Midland Technologies, 34374 E Frontage Rd, Bozeman, MIT 59715, tel 406-586-1190.

Call for Papers

Are you currently working in the area of RF technology? Do you design oscillators, power amplifiers, mixers, or PLLs? *RF Design Magazine* is once again sponsoring RF Technology Expo '88 to be held in Anaheim, CA on February 10-12, 1988. Your expertise is needed to create the best technical program yet. Individual papers and complete three-paper sessions are needed on RF, analog, or high-speed digital topics. For complete information on Expo '88, write Gary A. Breed, K9AY, Editor, *RF Design*, 6300 S Syracuse Way, Suite 650, Englewood, CO 80111, or tel 303-220-0600 for complete information.

Table of Equivalent TTL-IC Values

[This table is reprinted from the December 1985 *RadioAmater*, the journal of the Yugoslavia Amateur Radio Society.—Ed.]

TEXAS INSTR	FAIRCHILD	PHILIPS	SIEMENS	NATIONAL SEMICOND	NEC	RFT	USSR
SN7400N	F9N00PC	FJH131	FLH101	DM8000N	μPB201	D110C	K155LA3
SN7401N	F9N01PC	FJH231	FLH201	DM8001N	μPB215		K155LA8
SN7402N	F9N02PC	FJH221	FLH191	DM8002N	μPB232		K155LE1
SN7403N	F9N03PC	FJH291	FLH291	DM8003N		D103C	
SN7404N	F9N04PC	FJH241	FLH211	DM8004N	μPB235		K155LN1
SN7405N	F9N05PC	FJH251	FLH271	DM8005N	μPB236		K155LN2
SN7406N	F9N06PC		FLH481				K155LN3
SN7407N	F9N07PC		FLH491				K155LN4
SN7408N	F9N08PC		FLH381		μPB234		K155LI1
SN7409N	F9N09PC		FLH391				
SN7410N	F9N10PC	FJH121	FLH111	DM8010N	μPB202	D110C	K155LA4
	F9N11PC		FLH581				
SN7412N	F9N12PC		FLH501				K155LA10
SN7413N	F9N13PC	FJL131	FLH351				K155TL1
SN7414N							K155TL2
SN7416N	F9N16PC		FLH481T				K155LN5
SN7417N	F9N17PC		FLH491T				
SN7420N	F9N20PC	FJH111	FLH121	DM8020N	μPB203	D120C	K155LA1
SN7423N	F9N23PC		FLH511				K155LE2
SN7425N	F9N25PC		FLH521				K155LE3
SN7426N	F9N26PC	FJH301	FLH291U			D126C	K155LA11
SN7427N	F9N27PC		FLH621				K155LE4
SN7430N	F9N30PC	FJH101	FLH131	DM8030N	μPB204	D130C	K155LA2
SN7432N	F9N32PC		FLH631				K155LL1
SN7437N	F9N37PC		FLH531		μPB237		K155LA12
SN7438N	F9N38PC		FLH541		μPB238		K155LA13
SN7440N	F9N40PC	FJH141	FLH141		μPB205	D140C	K155LA6
	F9315PC	FJL101		DM8041N			
SN7442AN	F9352PC	FJH261	FLH281	DM8042N			
SN7443AN	F9353PC		FLH361				
SN7444AN	F9354PC		FLH371	DM8044N			
SN7445N	F9345PC		FLL111				
SN7446AN	F9357APC		FLL121U			D146C	
SN7447AN	F9357BPC		FL121V			D147C	
SN7448N	F9358PC		FLH551	DM8048N			
SN7449N	F9359PC						
SN7450N	F9N50PC	FJH151	FLH151	DM8050N	μPB206	D150C	K155LR1
SN7451N	F9N51PC	FJH161	FLH161	DM8051N		D151C	
SN7453N	F9N53PC	FJH171	FLH171	DM8053N		D153C	
SN7454N	F9N54PC	FJH181	FLH181	DM8054N	μPB208	D154C	K155LR3
SN7460N	F9N60PC	FJY101	FLY101	DM8060N	μPB210	D160C	K155LD1
SN7470N	F9N70PC	FJJ101	FLJ101				
SN7472N	F9N72PC	FJJ111	FLJ111	DM8540N	μPB212	D172C	K155TV1
SN7473N	F9N73PC	FJJ121	FLJ121	DM8501N			
SN7474N	F9N74PC	FJJ131	FLJ141	DM8510N	μPB214	D174C	K155TM2
SN7475N	F9375PC	FJJ181	FLJ151	DM8550N	μPB217		K155TM7
SN7476N	F9N76PC	FJJ191	FLJ131	DM8500N			
SN7477N	F9377PC						K155TM5
SN7480N	F9380PC	FJH191	FLH221				K155IM1
SN7481N	F93407APC		FLQ111			D181C	K155RU1
SN7483AN	F9383PC	FJH211	FLH241	DM8283N	μPB230		K155IM3
SN7484AN			FLQ121		μPB2084		K155RU3
SN7485N			FLH431				
SN7486N	F9N86PC	FJH271	FLH341	DM8086	μPB2086		K155LP5
SN7488AN	F93434PC		FLR101				
SN7489N	F93403PC		FLQ101				
SN7490AN	F9390PC	FJJ141	FLJ161	DM8530	μPB219		K155IE2
SN7491AN	F9391PC	FJJ151	FLJ221			D191C	
SN7492AN	F9392PC	FJJ251	FLJ171	DM8532	μPB222		K155IE4
SN7493AN	F9393PC	FJJ211	FLJ181	DM8533	μPB223		K155IE5
SN7494N	F9394C		FLJ231				
SN7495AN	F9395PC	FJJ231	FLJ191	DM8580	μPB226	D195C	K155IR1
SN7496N	F9396PC	FJJ241	FLJ261				
SN74100N			FLJ301				
SN74107N	F9N107PC	FJJ261	FLJ271				

TEXAS INSTR	FAIRCHILD	PHILIPS	SIEMENS	NATIONAL SEMICOND	NEC	RFT	USSR
29000N	F9000PC		FLJ281				
29001N	F9001PC		FLJ291				
SN74121N	F9603PC	FJK101	FLK101				K155AG1
SN74122N			FLK111				
SN74123N			FLK121		μPB2123		K155AG3
SN74125N							K155LP8
SN74128N							K155LE6
SN74132N			FLH601				K155TL3
SN74141N	F93141PC	FJL151	FLL101				K155ID1
SN74142N			FLL151				
SN74143N			FLL171				
SN74144N			FLL171T				
SN74145N	F93145PC		FLL111T				
SN74147N			74147				
SN74148N			74148				
SN74150N	F93150PC		FLY111				K155KP1
SN74151AN	F93151PC		FLY121		μPB2151		K155KP7
SN74152AN	F93152PC						K155KP5
SN74153N	F93153PC		FLY131				K155KP2
SN74154N	F9311PC	FJH341	FLY141				K155ID3
SN74155N		FJH491	FLY151				K155ID4
SN74156N			FLY161				
SN74157N	F9322PC		FLY171				
SN74160N	F9310PC		FLJ401				K155IE9
SN74161N	F9316PC		FLJ411				
SN74162N			FLJ421				
SN74163N			FLJ431				
SN74164N	F93164PC		FLJ441				
SN74165N	F93165PC		FLJ451				
SN74166N			FLJ461				
SN74167N			FLJ471				
SN74170N			FLQ131				K155RP1
SN74172N			74172				
SN74173N			74173				K155IR15
SN74174N			FLJ531				
SN74175N			FLJ541		μPB2175		K155TM8
SN74176N	F93176PC		74176				
SN74177N	F93177PC		74177				
SN74178N	F93178PC		74178				
SN74179N	F93179PC		74179				
SN74180N	F93180PC	FJH281	FLH421		μPB2180		K155IP2
SN74181N	F9341PC	FJH451	FLH401				K155IP3
SN74182N	F9342PC		FLH411				K155IP4
SN74184N			FLH561				K155PR6
SN74185N			FLH571				K155PR7
SN74287N	F93406PC		FLR111				K155RE21-24
SN74190N	F93190PC		FLJ201				
SN74191N	F93191PC		FLJ211				
SN74192N	F9360PC		FLJ241	DM8560	μPB2192	D192C	K155IE6
SN74193N	F9366PC	FJJ411	FLJ251	DM8563	μPB2193	D193C	K155IE7
SN74194N			FLJ551				
SN74195N	F9300PC		FLJ561				
SN74196N	F93196PC		FLJ381				
SN74197N	F93197PC		FLJ391				
SN74198N	F93198PC		FLJ311		μPB2198		K155IR13
SN74199N			FLJ321				
SN74200N			FLQ141				
SN74278N			74278				
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SN74283N			74283				
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SN74298N			74298				
SN74365N							K155LP10
SN74366N							K155LN6
SN74367N							K155LL11