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ABOUT THE COVER

Used and surplus equipment make an ideal VHF/UHF/microwave test station. Turn to page 12 for tips on choosing the necessary gear to get the job done.

THE AMERICAN RADIO RELAY LEAGUE, INC

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

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

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

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

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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...

AMSAT Joins *QEX*

You may have noticed *QEX*'s new subtitle: ARRL Experimenters' Exchange and AMSAT Satellite Journal. Actually, the possibility of this merger has been discussed on and off for several years. The problem was how to get technical material in the hands of satellite experimenters and operators. Both ARRL and AMSAT have a stake in the problem, which relates to how these two organizations serve the needs of their members. It has been apparent for some time that both organizations could improve the delivery of technical material to their members by some division of labor. However, it took several years and some experimentation to work out a viable approach.

Longtime AMSAT members will remember the progression from the *AMSAT Newsletter* to *Orbit* to the *Satellite Journal*. Over the years, publishing such periodicals proved to be too ambitious to be sustained by a purely volunteer effort. ARRL, by virtue of its large membership base, has an economy of scale that permits hiring of staff and as such can meet publication schedules with a high degree of reliability. Another concern was how much of AMSAT's dues income should be spent for periodicals. Several surveys indicated that AMSAT members wanted regular information, but preferred to maximize the part of the budget that goes into satellite projects. These and other considerations went into the final joint ARRL-AMSAT *QEX* venture. The bottom line is that each organization ends up doing that part of the job they do best and are able to deliver quality publications that are specifically targeted to the needs of their members. Both organizations benefit by being able to offer a better product.

This month we are pleased to add another name to the *QEX* masthead: Associate Editor Dr. Ron Long, W8GUS. Ron is a full professor of Electrical Engineering at the Ohio State University in Columbus and is a member of the Phi Beta Kappa honorary fraternity. Besides his impressive academic credentials, he is an active amateur, a Life member of ARRL and a member of AMSAT. As AMSAT's designee, Ron will be responsible for all amateur satellite material to be published in *QEX*. All satellite-related manuscripts should be sent to Ron at 1516 Essex Rd, Columbia, OH 43221. Welcome to *QEX*, Ron. May this be an enduring and productive association.

In case you missed the announcement in *QST* and the September issue of *QEX*, the ARRL will start paying honorariums for *QST* and *QEX* articles beginning with the January 1987 issues. The purpose of this change in long-term policy is to provide a steady flow of high-quality manuscripts. While you won't get rich, the honorariums should offset the out-of-pocket expenses of authoring and give you a bit extra toward your next toys.—W4RI

Correspondence

Terminations for the C64

The usual approach to creating a dummy load is to gather a bunch of resistors and pack them into an empty tobacco can. This works well for HF, if a 2:1 or less SWR is what you want. However, if a noise bridge is involved, you might want to check the reading for a "pure" 50-ohm setting. This means that the load should be accurate. For UHF/VHF work, the demands on a load such as this are ever increasing.

The tobacco can termination (TCT), with radially arranged resistors, has the drawback of a sudden change in the way an incoming wave sees what it hits. The wave may spread along each radial resistor lead, but not without an increase of capacitance to ground. Or, the total current bumps into one resistor at the same instant, then bumps out. There are many inconsistencies that take place in the dummy load at the same time that have to be dealt with. This is what causes reflections.

The BASIC program offers a better approach of damping the wave gradually. The little reflections that occur along the path will be attenuated as they try to make their way back through the resistors. This means less reflections and thus a better match.

I have constructed several of the TCTs using ordinary carbon-film resistors. They make a decent load up to a few gigahertz. Composite resistors would work better in this application.

The program begins with a three-element network. I assume you do not need a program to tell you how to arrange one or two. With four elements, as well as five, there is only one arrangement that will work. With six elements, there are two ways to arrange them. I have presented a solution for both.

For the "connoisseur," I will mention that the person starting with a serial element tends to start out slightly inductive, while the one with two parallel elements is slightly capacitive. The power handling can be increased if the elements that are ungrounded at one end (less cooling) are spared some of the power. This program provides for such action. The RATIO prompt at the beginning can be answered with 0.8 for example, making the power development in the ungrounded elements 80% of what it otherwise would have been. Once you experiment with this value, try several others around the wanted value.—*Carl G. Lodstrom, SM6MOM/W6, 4317 Verano Dr, Carpinteria, CA 93013*

The special characters in this program represent the following commands:
The inverted heart shown in lines 5, 300, 400 and 600 means home/clear screen. The inverted Q in lines 311, 319, 360, 370, 380, 411, 419, 460, 470, 480, 490, 511, 519, 570, 580, 590, 611, 619, 623, 624, 625, 651, 659, 665, 666 and 667 stands for cursor down. And, in line 664, the inverted circle represents cursor up. The program is written in standard BASIC, and by removing these characters, you should be able to calculate terminations on any computer.

```
3 REM THE UN-GROUNDED RESISTORS GET LESS
  COOLING. BY SELECTING I.E. R=0.8 THEY
4 REM GET THAT FRACTION OF THE POWER,
  AND THE OTHERS GET A BIT MORE.
5 PRINT"♥     TERMINATION NETWORKS"
10 INPUT"ELEMENTS (2<E<7)";N
20 INPUT"IMPEDANCE";Z
30 INPUT"RATIO";R
40 IF N<3 THEN GOTO 5
50 G=100*N
60 IF N=3 THEN GOTO 300
70 IF N=4 THEN GOTO 400
80 IF N=5 THEN GOTO 500
90 IF N=6 THEN GOTO 600
100 GOTO 1000
300 PRINT"♥    3 ELEMENT TERMINATION, "Z"OHM"
311 PRINT"■■■              ┬"
312 PRINT"                 ┴"
313 PRINT"                 2| "
314 PRINT"             _   ┬"
315 PRINT"      o—┤1├——┤"
316 PRINT"             ‾   ┴"
317 PRINT"                 3| "
318 PRINT"                 ┬"
319 PRINT"                 ┴■■■"
320 P1=R:P2=(N-P1)/2
330 U=SQR(N*Z):I=SQR(N/Z)
340 R1=P1/I↑2
350 R2=P2/((I/2)↑2):R3=R2
360 PRINT"■■■■■■■",,"R1=";R1
370 PRINT,,"■■R2=";R2
380 PRINT,,"■■R3=";R3
399 END
400 PRINT"♥    4 ELEMENT TERMINATION, "Z"OHM"
411 PRINT"■■■              ┬"
412 PRINT"                 ┴"
413 PRINT"                 2| "
414 PRINT"             _   ┬  _"
415 PRINT"      o—┤1├—┼—┤4├"
416 PRINT"             ‾   ┴  ‾"
417 PRINT"                 3| "
418 PRINT"                 ┬"
419 PRINT"                 ┴■■■"
420 U=SQR(N*Z):I=SQR(N/Z)
430 R1=R/I↑2
440 U2=U-(I*R1)
450 R2=U2*3/I:R3=R2:R4=R2
460 PRINT"■■■■■■",,"R1=";R1
470 PRINT"■■",,"R2=";R2
480 PRINT"■■",,"R3=";R3
490 PRINT"■■",,"R4=";R4
499 END
500 PRINT"♥    5 ELEMENT TERMINATION, "Z"OHM"
510 REM INPUT POWER ASSUMED TO BE 5 W
511 PRINT"■■■         ┬       ┬"
512 PRINT"           ┴       ┴"
513 PRINT"           |1|     4| "
514 PRINT"           ┬   _   ┬"
515 PRINT"      o——┼—┤3├——┤"
516 PRINT"           ┴   ‾   ┴"
517 PRINT"           2|      5| "
518 PRINT"           ┬       ┬"
519 PRINT"           ┴       ┴■■■"
520 P1=(5-R)/4:U=SQR(Z*5):R1=U↑2/P1
530 S2=1/Z-1/(R1/2):I=U*S2:R3=R/I↑2
540 R4=P1/(I/2)↑2
570 PRINT"■■■■■■■",,"R1=R2=";R1
580 PRINT,,"■■    R3=";R3
590 PRINT,,"■■R4=R5=";R4
599 END
600 PRINT"♥    6 ELEMENT TERMINATION, "Z"OHM"
610 REM INPUT POWER ASSUMED TO BE 6 W
611 PRINT"■■■         ┬       ┬"
612 PRINT"           ┴       ┴"
613 PRINT"           |1|     4| "
614 PRINT"           ┬   _   ┬  _"
615 PRINT"      o——┼—┤3├——┼—┤6├"
616 PRINT"           ┴   ‾   ┴  ‾"
617 PRINT"           2|      5| "
618 PRINT"           ┬       ┬"
619 PRINT"           ┴       ┴■■■"
620 P1=(6-R)/5:U=SQR(Z*6):R1=U↑2/P1
621 S=1/Z-1/(R1/2):I=U*S:R3=R/I↑2
622 R4=P1/(I/3)↑2
623 PRINT"■■■■■■■",," R1=R2=";R1
624 PRINT,,"■■    R3=";R3
625 PRINT,,"■■R4,5,6=";R4
650 P1=(6-R)/5:U=SQR(Z*6):R1=U↑2/P1
651 PRINT"■■■           ┬       ┬"
652 PRINT"              ┴       ┴"
653 PRINT"              2|      5| "
654 PRINT"          _   ┬   _   ┬"
655 PRINT"    o—┤1├—┼—┤4├——┤"
656 PRINT"          ‾   ┴   ‾   ┴"
657 PRINT"              3|      6| "
658 PRINT"              ┬       ┬"
659 PRINT"              ┴       ┴■■■"
660 P1=(6-R*2)/4:U=SQR(Z*6)
661 I=SQR(6/Z):R1=R/I↑2:U2=I*Z-I*R1
662 R2=U2↑2/P1:I2=I-2*U2/R2
663 R4=R/I2↑2:R5=P1/(I2/2)↑2
664 PRINT,,"●●●●●●●●●●●●●■■        R1=";R1
665 PRINT,,"■■ R2=R3=";R2
666 PRINT,,"■■     R4=";R4
667 PRINT,,"■■ R5=R6=";R5
699 END
```

Practical Spread Spectrum: A Simple Clock Synchronization Scheme

By Andre Kesteloot, N4ICK
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On June 1, 1986, US Amateur Radio operators were given authorization to use a transmission method known as spread spectrum.[1] For a good theoretical coverage of the subject, refer to chapter 21 of *The 1986 ARRL Handbook*.[2] In addition, a condensed report on spread-spectrum experiments conducted by the Amateur Radio Research and Development Corporation (AMRAD) has been published in a recent issue of *QST*.[3]

In Amateur Radio spread-spectrum transmissions, in addition to the application of some traditional method of modulation to an RF-carrier, a pseudo-random code is used either to (a) alter the phase of the carrier (direct sequence), or (b) force the carrier to hop from one frequency to another (frequency hopping). This pseudo-random code is generated in the transmitter at a certain clock frequency. If that clock and the original code are available at the receiving site, decoding (despreading) can be achieved.

The code can be easily dismissed from the picture. The only pseudo-random sequences presently authorized in Part 97 of the latest *FCC Rule Book* are those that can be obtained from the output of one binary linear-feedback shift register either 7, 13 or 19 stages long, and using only certain feedback taps (see note 1).[4] Thus, both transmitting and receiving parties can agree in advance on a particular pseudo-random code and set up their equipment accordingly.

The clock poses a much more intricate problem. In 1983, William Sabin, WØIYH, suggested that one solution is for both parties to be synchronized to the same external reference, such as WWV.[5] Choosing WWV as a source was plausible at the time because amateur HF spread spectrum was still being considered as a possibility. The new FCC ruling, however, allows for spread-spectrum transmissions to take place only above 420 MHz. This effectively restricts the coverage of any given spread-spectrum transmission to a relatively small geographical area, possibly that of a given community (at least until spread-spectrum repeaters are deployed)! If that is the case, then the local TV station's signals can be used as a source of accurate clock pulses (see Fig 1).

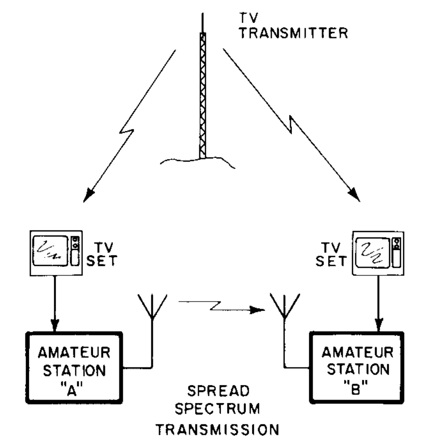

Fig 1—All US television stations transmit horizontal and vertical synchronization pulses that amateurs can use as clock pulses for spread-spectrum applications.

All US TV stations transmit horizontal synchronization pulses (H sync) at approximately 15,750 Hz and vertical synchronization pulses (V sync) at approximately 60 Hz. These sync pulses can be used as clock pulses for amateur spread-spectrum applications. At this time, AMRAD members are interested in frequency hopping at a fairly slow rate (between 10 and 60 hops per second) and choosing the V sync as a clock signal seemed logical for a first attempt.

The Arrangement

This article describes a practical frequency-hopping scheme using the discussed approach. A model for spread-spectrum transmissions was built for, and demonstrated at, the June 2, 1986 AMRAD meeting in Vienna, VA. A block diagram of the general arrangement used for the demonstration is shown in Fig 2.

Refer to Fig 3. Vertical sync pulses are readily available at the deflection yokes of any TV set. Since most TV sets have one side of the mains connected to the chassis, the use of an optoisolator stage is strongly recommended as an interface between the TV set and the ham gear. The 60-Hz V sync pulses are fed to a shaping stage and then used to feed a divide-by-N stage, the output of which is the hopping clock frequency. (To make the hopping frequency 15 hops/second, make N = 4, etc.) If both parties use the same arrangement, they will obtain clock pulses of the same frequency. To ensure that these clock pulses are actually in phase, we need now only reset both dividers simultaneously. This is achieved by one station issuing an audio tone burst, used as the reset signal at both transmitting and receiving sites. This burst needs to be sent only once, in clear, before spread-spectrum transmissions may commence. (The audio burst can be transmitted on the spread-spectrum service frequency, or over a local FM repeater to allow for an Amateur Radio net.) From this point on, the two clocks will be in sync unless the TV signal to either ham station is momentarily lost (fading, and the like).

The Circuit

Refer to Fig 3: A 555 (U2) is connected as an astable pulse generator to oscillate continuously at about 2 kHz. The exact frequency is determined by the setting of the 25-kilohm potentiometer, while the symmetry (duty-cycle) of the waveform is adjusted by means of the 100-kilohm potentiometer. Another 555 (U1) is connected as a monostable generator and produces one pulse (of about a one-second duration) every time pin 2 is grounded (depress the reset button). This pulse opens a 4011 gate and sends a tone burst to the transmitter's microphone input. The same pulse is fed to a pulse stretcher consisting of a 1-Megohm/3.3-μF/ 4049 combination, the output of which is used as the PTT signal. (Pulse stretching ensures that the transmitter stays on a little longer than the duration of the tone burst.)

Each station uses the same burst-decoding circuit to allow for an easier decoder adjustment. The audio tone

[1]Notes appear on page 7.

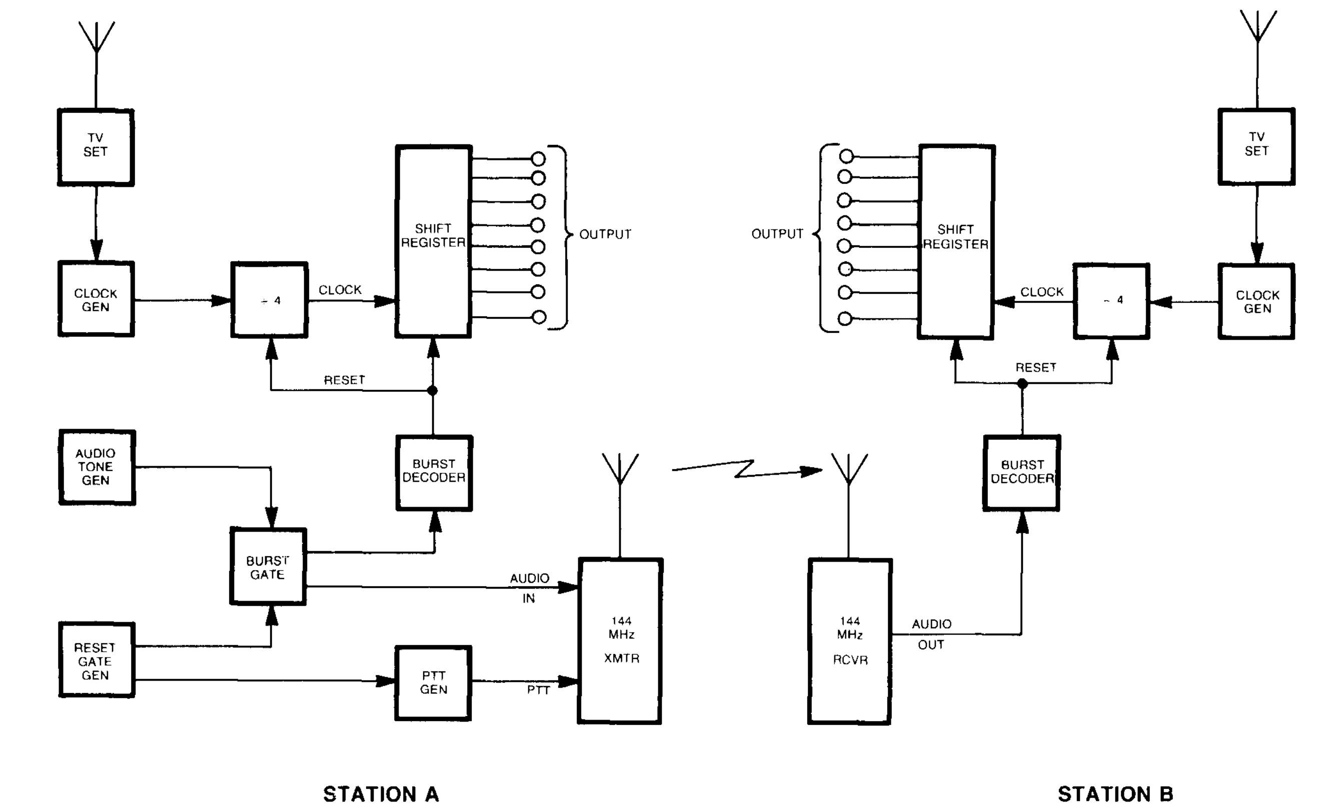

Fig 2—A block diagram of the AMRAD station arrangements used in their June 1986 demonstration.

burst, when applied to pin 3 of the 567 tone decoder, produces a negative-going output at pin 8. The negative pulse resets the 4018 divide-by-N and clears the 74164 shift register.

The 4018 divide-by-N stage is fed 60-Hz (V) pulses. Its output is the clock signal used to drive a pseudo-random generator of the type allowed by the FCC (see note 1). For our model, a simple 7-stage serial-in, parallel-out shift register was chosen with feedback taps from stages 1 and 7. A 74164 and a 7486 were used. (The 4015 and 4070-CMOS chips could have been used instead to maintain an all-CMOS design, but I had the TTL chips in my junkbox!) The 74164 is an 8-stage shift register and the 7486 is a quad XOR gate. One section of the 7486 is used to combine the feedback from taps 1 and 7, and another section is used as an inverter. The purpose of the inverter can be understood by considering the operation of the shift-register stage: When the 74164 is reset, all register-stage outputs are set to 0. Thus, feedback taps 1 and 7 are 0s, and the output of the XOR stage is also 0, feeding a new 0 to the input of the shift register. This arrangement would normally "hang up" the shift-register in a nonallowable state. By adding the inverter stage (one section of the 7486), the 0 output of the XOR stage, obtained on reset, is changed to a 1 and the counting sequence can start over again.

The outputs of the shift-register stage, at pins 3, 4, 5, 6, 10, 11 and 12 are now the complements of the original sequence. But since common emitter transistor (or inverting buffer) stages are used to interface with the ham gear, the original sequence, as specified by the FCC, is restored. Note that the tone burst detector's output resets (clears) the shift register and the divider stage simultaneously.

The pseudo-random sequence generated by this described arrangement is shown in Table 1. The numbers listed are the decimal equivalents of the binary states appearing at the 74164's output pins.

The Demonstration

During the AMRAD demonstration, two TV sets were used to simulate a real-life situation. Each set was modified to produce V sync pulses. Both TV sets were tuned to the same local channel. (As luck would have it, the location used for the AMRAD meeting was a genuine RF hole and TV reception was poor at best. Nevertheless, acceptable sync pulses were derived from each set.) The output of each TV set was connected to a separate pulse-shaping stage and a shift register. Each station also had its own separate audio burst detector. An audio tone burst used to synchronize both boards was sent from one station to the other. This was done using 144-MHz transceivers. Both stations remained in phase for the duration of the lecture (about 90 minutes).

Comments

A few words of explanation and some suggestions may be in order

a) A 7-stage shift register was chosen because its parallel output interfaces easily with any parallel scheme, and specifically with the spread-spectrum sets designed several years ago by Chuck Phillips, N4EZV. (At the time, Chuck used extremely stable crystal oscillators in each set, from which he derived clock signals. Clocks were reset whenever sync was lost.)

b) Although a simple serial-in, parallel-out shift register was used for the demonstration, a more elaborate parallel loading scheme could be envisaged. This would allow for different "words" to be loaded initially in the shift registers, thereby permitting different shift se-

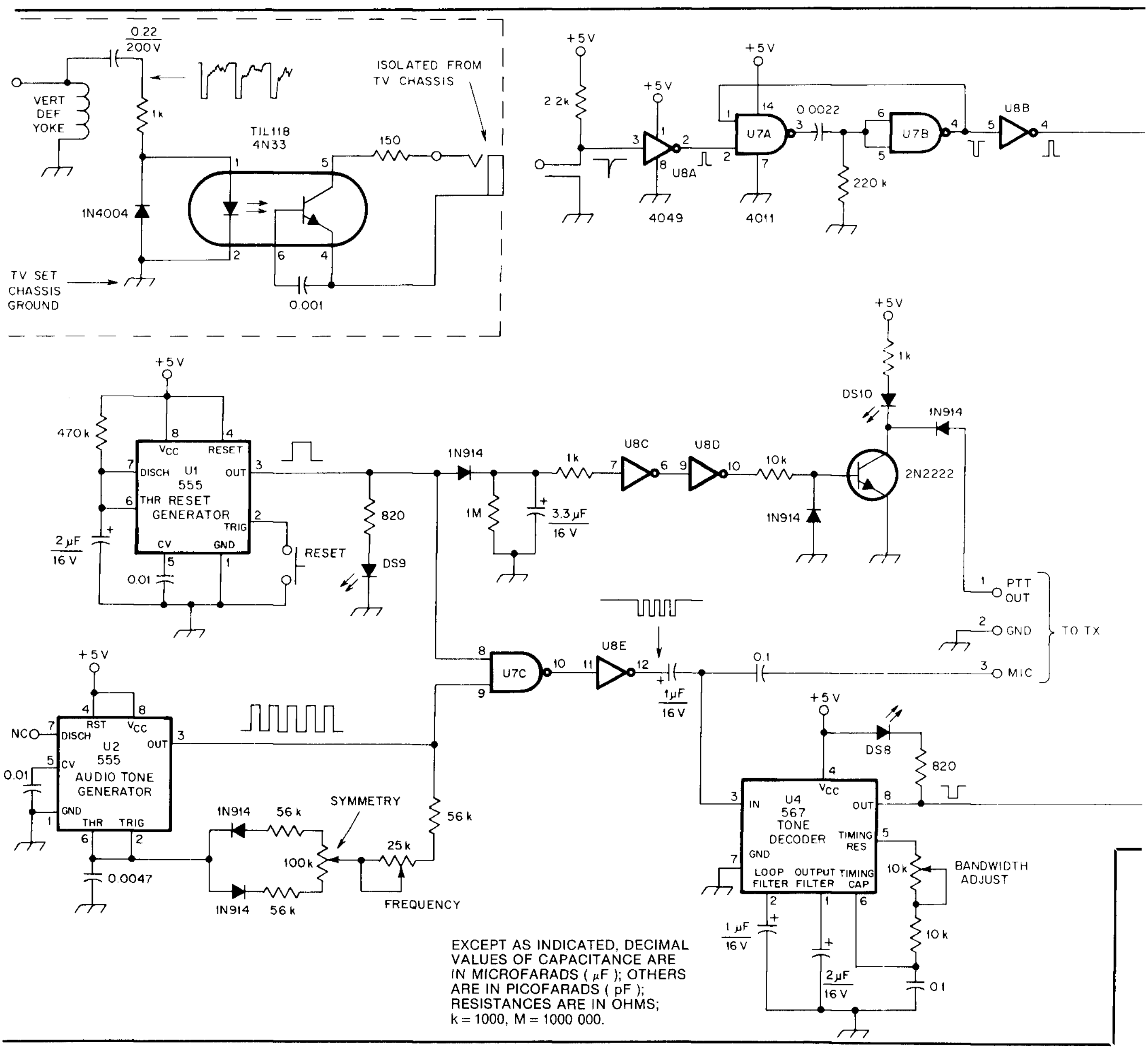

Table 1

Pseudo-random Sequence Generated by the Described Circuit

						0001110	14	0110001	49	1111010	122
						1000111	71	0011000	24	0111101	61
						1100011	99	1001100	76	0011110	30
0000000	0	1000100	68	0010000	16	1110001	113	0100110	38	1001111	79
1000000	64	0100010	34	1001000	72	1111000	120	1010011	83	1100111	103
0100000	32	1010001	81	0100100	36	0111100	60	1101001	105	1110011	115
1010000	80	1101000	104	1010010	82	1011110	94	1110100	116	1111001	121
0101000	40	0110100	52	0101001	41	0101111	47	0111010	58	1111100	124
1010100	84	1011010	90	0010100	20	0010111	23	1011101	93	0111110	62
0101010	42	0101101	45	1001010	74	0001011	11	1101110	110	1011111	95
1010101	85	0010110	22	0100101	37	0000101	05	0110111	55	1101111	111
1101010	106	1001011	75	0010010	18	0000010	02	0011011	27	1110111	119
0110101	53	1100101	101	1001001	73	1000001	65	0001101	13	1111011	123
0011010	26	1110010	114	1100100	100	1100000	96	0000110	06	1111101	125
1001101	77	0111001	57	0110010	50	0110000	48	1000011	67	1111110	126
1100110	102	0011100	28	1011001	89	1011000	88	1100001	97	0111111	63
0110011	51	1001110	78	1101100	108	0101100	44	1110000	112	0011111	31
0011001	25	0100111	39	0110110	54	1010110	86	0111000	56	0001111	15
0001100	12	0010011	19	1011011	91	0101011	43	1011100	92	0000111	07
1000110	70	0001001	09	1101101	109	0010101	21	0101110	46	0000011	03
0100011	35	0000100	04	1110110	118	0001010	10	1010111	87	0000001	01
0010001	17	1000010	66	0111011	59	1000101	69	1101011	107	0000000	00
0001000	08	0100001	33	0011101	29	1100010	98	1110101	117		

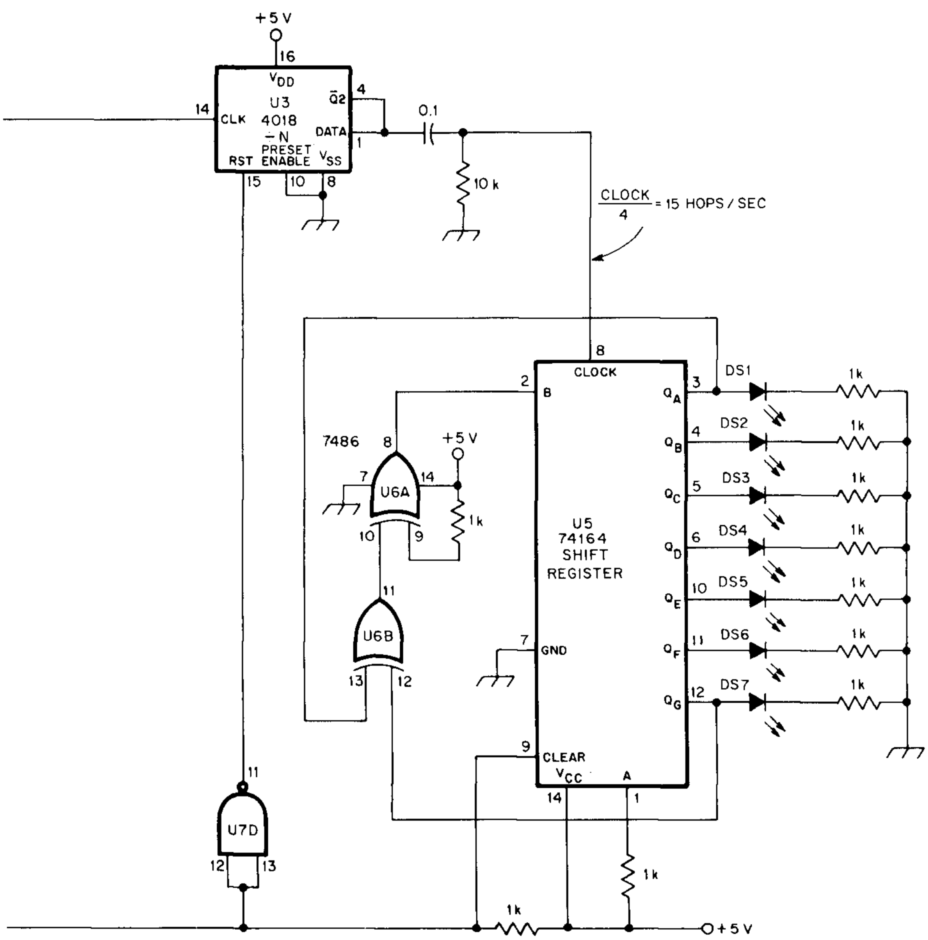

Fig 3—The schematic diagram of demo station A. Station B is similar except that the 555 reset generator, 555 audio pulse generator, audio-burst gate and the PTT generator are not needed. Audio output from the 144-MHz receiver is connected to pin 3 of the 567 audio-burst detector.

quences and, hence, operation of several different stations on the same frequency band with a minimum of interference.

c) Other external references are available: In addition to WWV, already suggested by William Sabin, Loran C, Satnav satellites and our ubiquitous 60-Hz mains readily come to mind. Each has advantages; each has drawbacks. The TV sync pulses, on the other hand, are easy to obtain. In practice, a portable amateur station would not require a complete TV set, but only a TV tuner, an IF stage and an AM detector followed by a sync separator to produce acceptable V sync pulses. Inexpensive all-band receivers (which have an AM detector) could be modified to cover part of the TV channels. Modern portable FM/VHF TV-sound receivers, however, are often only equipped with a combined IF amplifier and FM detector single-chip arrangement which does not easily lend itself to modification for AM detection.

d) Whichever external reference system is favored, remember that any such scheme could be particularly attractive in future single-sideband frequency hopping applications, as no continuous carrier would need be transmitted to convey clock information. The only output would then be the instantaneous hopping frequency, further reducing the likelihood of interference.

e) The 555/567 audio-burst generator and decoder combination I have used (for the sake of expediency) could profitably be replaced by a more reliable (and easier to adjust) dual-tone, multi-frequency (DTMF) decoder. This would allow for a standard transceiver's DTMF pad to be used as the source of reset pulses. (Radio-Shack sells a DTMF decoder chip requiring no adjustment.)

f) In the arrangement used for the AMRAD demonstration, (Fig 3), the trailing edge of the push-to-talk pulse was controlled by a half monostable to keep the transmitter on slightly longer than the audio burst. It also ensured that the receiver's squelch tail did not interfere with the operation of the burst detector.

g) A maximal-length 7-stage shift register requires 127 clock pulses to complete one sequence. For high-speed spread spectrum, the H sync pulses could be used as a clock, as follows: There are 262.5 TV lines (H sync) per field, two fields (V sync) per frame and 30 frames per second. By feeding the H sync pulses to a divide-by-2, 131 clock pulses per V sync pulse could be obtained. (A "flywheel" circuit would be required to oversee that the equalization pulses do not create false clock signals.) The V sync pulse could be used to trigger a monostable of 4H duration which would be the shift-register reset pulse. Thus, there would be exactly 127 clock pulses until the next reset pulse. The audio burst scheme could then be eliminated and the frequency-hopping rate, or the carrier phase-reversal rate, would be 7650 per second. With this arrangement, if there were to be a temporary loss of clock synchronization between the two amateur stations, sync would automatically be restored after a maximum of 1/60th of a second. This could be a particularly useful feature for mobile spread-spectrum applications.

If the audio burst scheme is retained, then any submultiple of H (between 15,750 Hz and 60 Hz) can be used as a clock pulse, simply by feeding H sync to a divide-by-N. Hence, by making N = 150, 105 hops per second is obtainable, and so on.

h) The scheme described in this article is not necessarily the best way to achieve clock synchronization. It is only my version 1.0, ie, a simple way of doing it. It is offered here with the hope that other radio amateurs will use it as a starting point to design their own equipment.

I thank Chuck Phillips, N4EZV, with whom I am exploring several other practical frequency-hopping methods. My thanks are also extended to Terry Fox, WB4JFI, David Borden, K8MMO, and Hal Feinstein, WB3KDU, three other AMRAD members whose encouragements helped me to complete the project.

Notes

[1]D. Newkirk, "Our New Spread Spectrum Rules" *QST*, Apr 1986, p 45.

[2]M. Wilson, ed., *The 1986 ARRL Handbook*, (Newington: ARRL, 1986) pp 21-7 to 21-14.

[3]H. Feinstein, "Spread Spectrum: Frequency Hopping, Direct Sequence and You," *QST*, Jun 1986, p 42.

[4]R. Palm, ed., *The FCC Rule Book*, (Newington: ARRL, 1986).

[5]W. Sabin, "Spread-Spectrum Applications in Amateur Radio," *QST*, Jul 1983, p 16.

Inductance and Capacitance Magnification

By Jacob Z. Schanker, W2STM
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Inductance Magnification

When designing LC matching networks (transmitter output networks and antenna tuners), there are often times when the electrical network requirements call for a larger value of inductance than physical constraints permit, or than is otherwise available. Particularly in ham designs, builders often have to "make do" with such a coil in the parts box. The technique described here shows that it is possible to obtain an effective value of inductance much higher than a coil's intrinsic inductance. This *inductance magnification* is achieved by shunting the coil with a properly selected value of capacitance.

The curve in Fig 1 enables the proper value of shunt capacitance to be quickly determined for any desired degree of inductance magnification. The vertical axis gives the desired magnification factor L_{eff}/L_{coil}, while the horizontal axis is in terms of f/f_o, where f equals the frequency at which inductance magnification is desired (frequency of operation), and

$$f_o = \frac{1}{2\pi\sqrt{L_{coil} \times C_{shunt}}} \qquad \text{(Eq 1)}$$

is the resonant frequency of the parallel LC combination. From the curve, it should be apparent that for this effect to be used, the frequency of operation, f, must be less than f_o.

It should also be noted that the inductance magnification effect is highly frequency sensitive. That is, the desired value of inductance is obtained only at the design frequency. The effective inductance will be smaller below the design frequency, and larger above it. This is understandable when the inductance magnification is viewed as a resonant effect. This frequency sensitivity may rule out the use of inductance magnification in many applications. However, where operation is confined to a single frequency or a limited frequency range, inductance magnification can be a very useful technique.

An example will demonstrate the technique and the use of the curve of Fig 1.

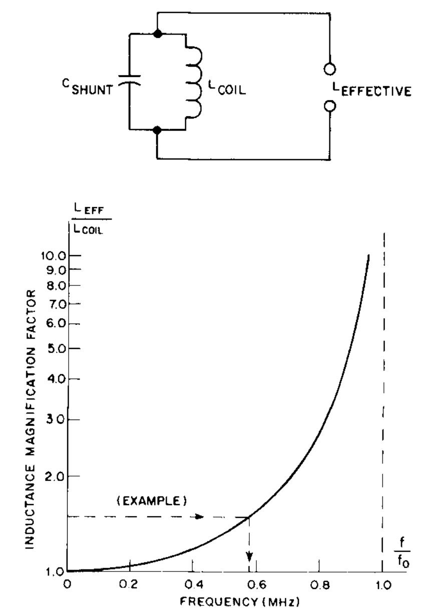

Fig 1—The parallel circuit and curve, together with the example in the text, shows how to determine the correct value of shunting capacitance for any degree of inductance magnification.

Example

An inductance of 42 μH is required in an antenna matching network at 1.9 MHz. The closest inductance value available is a 28 μH coil. The curve in Fig 1 will be used to select a value of shunt capacitance which will give the desired 42 μH effective inductance.

First, the ratio

$$L_{eff}/L_{coil} = 41.8/28 = 1.5 \qquad \text{(Eq 2)}$$

From the curve, for $L_{eff}/L_{coil} = 1.5$ on the vertical axis, it is found that $f/f_o = 0.58$ on the horizontal axis. Then, for f = 1.9 MHz, $f_o = 1.9/0.58 = 3.28$. The formula for f_o is then solved for C_{shunt}. To do this, it is convenient to rearrange the formula in the form

$$C_{shunt} = \frac{1}{4\pi^2 f_o^2 L_{coil}} \qquad \text{(Eq 3)}$$

Solving Eq 3, C_{shunt} = 84.3 pF. Thus, shunting the 28 μH coil with an 84.3 pF capacitor will make the combination appear to the rest of the circuit as if it were a 42-μH inductor. In practice, the nearest standard value capacitor would be used, the resultant value of effective inductance calculated, and slight adjustment might be made in other circuit values.

Additional Comments

This technique is not new. We are simply looking at the familiar resonant circuit from a somewhat different perspective. A little thought may reveal further useful results. For instance, since the effective inductance is a function of the value of shunting capacitance, using a variable capacitor turns the fixed inductor into a variable inductor. Also, by analogy to inductance magnification, it is possible to obtain *capacitance magnification*.

Capacitance Magnification

We have just described how the addition of a properly selected shunt capacitance can magnify the effective inductance of a coil. Here, we describe a dual effect; the increase in the effective capacitance of a capacitor by the series connection of a properly selected value of inductance. The usefulness of such a technique should be obvious to anyone who has tried to build an antenna matching network, but found that just a little more capacitance was needed when the plates were already fully meshed. An application of this technique to a commercial Transmatch was published several years ago in *QST*.[1] Another use is in output pi networks, where a very large value of loading capacitance is needed on 160 and 80 meters.

The curve in Fig 2 enables the proper value of series inductance to be determined for any desired degree of capacitance magnification. As with inductance magnification, the vertical axis presents the desired magnification factor C_{eff}/C_{cap}. The horizontal axis is also in terms of the ratio f/f_o, where the frequency equals the capacitance magnification desired and

$$f_o = \frac{1}{2\pi\sqrt{L_{series} \times C_{cap.}}} \qquad \text{(Eq 4)}$$

Eq 4 is the resonant frequency of the series LC combination. The frequency of operation must be lower than the resonant frequency. Again, an example

[1] J. Schanker, "Extending Transmatch Range," *QST*, Apr 1980, p 46.

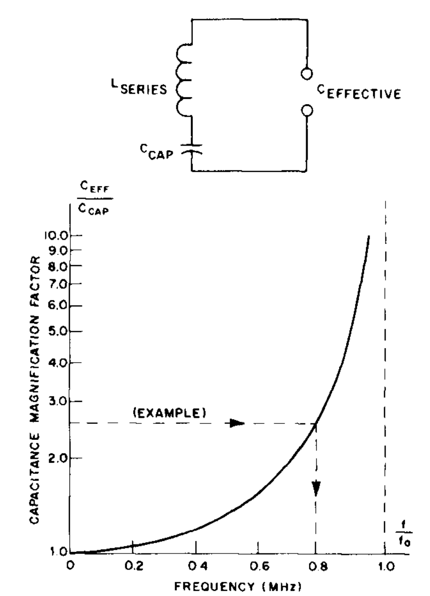

Fig 2—The series circuit and curve, together with the text's example, shows how to arrive at the proper value of series inductance to be determined for any degree of capacitance magnification.

will help explain the use of the curve.

Because capacitance magnification can be viewed as a resonance effect, it is highly frequency sensitive, particularly at larger values of magnification. A given value of effective capacitance is obtained only at a single frequency. Below the design frequency, the effective capacitance will be smaller. Above the design frequency, it will be larger. Over the limited frequency range typical of amateur bands, this variation may be acceptable. So, capacitance magnification is not a cure all, but can nonetheless be quite useful if applied with care.

Example

This example demonstrates two things: the use of the curve in Fig 2 and the calculation of the required value of series inductance for a given amount of capacitance magnification. Typically, a pi network operating in the 160-m band might require an output loading capacitor of about 2600 pF. A variable capacitor with this much capacitance is hard to find. Suppose that a 1000-pF variable capacitor was available. The capacitance magnification desired is then

$$C_{eff}/C_{cap} = 2600/1000 = 2.6. \quad \text{(Eq 5)}$$

Going to the curve in Fig 2, we find that for this magnification, $f/f_0 = 0.78$. Using 1.8 MHz as the operating frequency, f, and solving for $f_0 = 1.8\ \text{MHz}/0.78$, $f_0 = 2.3$ MHz.

This is the resonant frequency of the series LC combination. To find the value of the coil, we use the rearranged resonance formula

$$L_{series} = \frac{1}{4\pi^2 f_0^2 C_{cap}} \quad \text{(Eq 6)}$$

Inserting values,

$$L_{series} = \frac{1}{4\pi^2 (2.3 \times 10^6)^2 (1000 \times 10^{-12})}$$

$$= 4.79 \times 10^{-6}\ \text{H}. \quad \text{(Eq 7)}$$

Thus, a 4.79 μH coil in series with a 1000-pF capacitor, will appear like a 260-pF capacitor to the rest of the circuit.

Appendix

The derivation of the curve in Fig 1 is quite straightforward. The value of shunt capacitance required to achieve the desired amount of inductance magnification can be found by setting the admittance of the shunted coil capacitor combination equal to the admittance of the desired effective inductance. Referring to Fig 1, we have

$$\frac{1}{-j2\pi f L_{coil}} + j2\pi f C_{shunt} = \frac{1}{2\pi f L_{eff}} \quad \text{(Eq 8a)}$$

Solving for the shunt capacitance, C_{shunt}, results in

$$C_{shunt} = \frac{1}{(2\pi f)^2}\left[\frac{1}{L_{coil}} - \frac{1}{L_{eff}}\right] \quad \text{(Eq 8b)}$$

Eq 8a can be rearranged to form the generating equation for the curve. This is

$$\frac{L_{eff}}{L_{coil}} = \frac{1}{\left[1 - \frac{(2\pi f)^2}{(2\pi f_0)^2}\right]}$$

$$\text{where } f_0 = \frac{1}{2\pi\sqrt{L_{coil} \times C_{shunt}}} \quad \text{(Eq 8c)}$$

Bits

JAS-1: A Reality

Several issues ago, *QEX* carried information on the JAS-1 satellite. Scheduled for launch on August 1, 1986, the launch was postponed three times as a result of hardware problems and environmental threats (typhoon). However, on August 12, 1986, at 2047 hours, Japan OSCAR 12 (JO-12) reached new heights. While it has been reported that the JA transponder is functioning properly, users have been requested to use the lowest power level possible to complete communications. Here are the latest Keplerian Orbital Elements as of August 20:

Reference Epoch:	86230.26525652
Element set:	6
Inclination:	50.0097 deg
Right ascension of the ascending node:	236.4938 deg
Eccentricity:	0.0011125
Arg of perigee:	233.7423 deg
Mean anomoly:	353.0984 deg
Mean motion:	12.44393428 rev/day
Epoch revolution:	67
Decay rate:	−3.9e-07 rev/day2

[While AMSAT is currently calling JAS-1 Japan Oscar 12, the Japanese have named the satellite Fuji-OSCAR 12 (FO-12).]

JAS-1 Feedback

Refer to p 3 of the August 1986 issue of *QEX*. The article, "A PSK Demodulator for the JAS-1 Satellite," was originally written by the JAS-1 Committee of JARL and translated into English by Fujio Yamashita, JS1UKR. On p 6, line 20, variable crystal oscillator should read voltage controlled oscillator.

AMSAT Mode-S Transponder

By William D. McCaa, Jr, KØRZ
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The Phase 3C amateur satellite is currently scheduled for launch in mid-1987 on Ariane 4's first flight. The new satellite will include a narrowband transponder with its input at 435.625 MHz and its output at 2400.710 MHz (12.5 cm). A beacon output at 2400.640 MHz is also included.

The transponder is intended purely for experimental and educational purposes. It will provide an opportunity for OSCAR users to gain experience in receiving microwave frequencies from an Amateur Radio satellite. Construction of suitable 2400-MHz receiving apparatus should be aided by the wide availability of low-cost, crystal-controlled equipment intended for the commercial MDS service at 2150-2160 MHz.

Table 1
Mode-S Transponder Frequencies

Input Frequency to the S-Band Transponder (F_{in})	435.625 MHz
Input frequency from the Mode-B transponder	53.305 MHz
Local crystal-controlled oscillator (LO1)	42.605 MHz
Local crystal-controlled oscillator (LO2)	41.930 MHz
IF including filter (IF = Fin − LO1 − 382.32)	10.700 MHz
IF Filter Bandwidth	30.000 kHz
Beacon injection oscillator (BO)	10.630 MHz
3 × LO2 injection frequency	125.790 MHz
First upconversion frequency (FI = 3 × LO2 + IF)	136.490 MHz
18 × 3 × LO2 injection frequency	2264.220 MHz

Modulation

With some reservations, CW, NBFM or SSB modulation could be used with the Phase 3C transponder; it is a soft-limiting type. Since the received signal-to-noise ratio (SNR) will be less than 20 dB, SSB can be used through the transponder. This is because the intermodulation products introduced by the nonlinearity of the amplifier and limiter are generally more than 20 dB down and thus below the received noise level. This method of operation is successfully used in the Mode-L transponder on OSCAR 10. The transponder either operates in the beacon mode (400-baud PSK, 2400.640 MHz) or the transponder mode (30-kHz bandwidth). The bandwidth of the transponder is sufficient for one or two NBFM signals or four simultaneous SSB signals.

General Comments on Transponder Use

The transponder can be used for normal voice and data communications using NBFM, CW or SSB modulation as described. Doppler shifts at S-band frequencies can be up to 50 kHz, depending on the position of the satellite in its orbit. Since the Doppler shift will be minimum at apogee, it is planned that the beacon or transponder will only be turned near apogee.

SSB or CW requires less receiver bandwidth than NBFM. In addition to accommodating more signals in the passband, with reduced bandwidth the required receiver sensitivity or antenna size decreases for a given SNR. However, SSB and CW reception at 2401 MHz requires excellent receiver frequency control by a crystal-controlled converter. With NBFM modulation, the ground station receiver could use AFC to overcome receiver frequency drift and Dopper effects.

Transponder Description

The Mode-S transponder uses a portion of the Mode-B transponder's receiver. A buffered output at 53 MHz is taken from the Mode-B receiver's first IF, after AGC. The Mode-S transponder thus can be operated only when the Mode-B receiver is active. The Mode-S beacon, however, can be operated at any time. Table 1 details the frequencies used in the transponder.

The transponder has an effective isotropic radiated power (EIRP) of +17 dBW. The spacecraft antenna is a left hand circular 15-turn helix with a gain of 17 dBic. The uplink power at 435 MHz required for access will be the same as that required for Mode B, ie, about 1000-W EIRP maximum. The transponder current drain from the 14.0-V dc bus is 0.53 A. The 2401-MHz output power is 1.25 W. This represents an overall transponder efficiency of 17%. All spurious outputs are at least 40 dB down from the fundamental output.

Typical link calculations at 2.4 GHz with assumptions shown are:

Transmitter output power at antenna (1 W)	+0 dBW
Spacecraft antenna gain (15-turn helix)	+17 dBic
Spacecraft EIRP	+17 dBW
Free space path loss (24,860 mi at 2.4 GHz)	−192 dB
Signal level at receive antenna	−175 dBW
Receive antenna gain (1-m dish at 50% eff)	+25 dBic
Signal level at receiver	−150 dBW
Receiver sensitivity (75°K, 20-kHz BW)	−160 dBW
Received SNR	+10 dB

The transponder is composed of two separate packages. Package 1 (S-TX) is shown in Fig 1 and contains the S-band mixer, S-band amplifier and the 18-times multiplier. It is mounted at the end of one of the Phase 3C satellite arms, next to the Mode-B receiver. The package size measures 10 × 2.23 × 3 inches.

Fig 2 shows package 2. It contains the VHF stages, 10-V dc converter, beacon generator, 42-MHz oscillators, 3-times multiplier and the IHU computer interface. Package 2 is mounted on top of the Mode-B transmitter and measures 13.85 × 4.12 x 1.5 inches.

The Mode-S transponder underwent thermal vacuum testing in the Phase 3C spacecraft during May 1986. Since that time, it has undergone over 1000 hours of operation without a failure. The transponder has also been operated in the NBFM and SSB modes. SSB quality is good considering the mentioned limiting feature of the transponder.

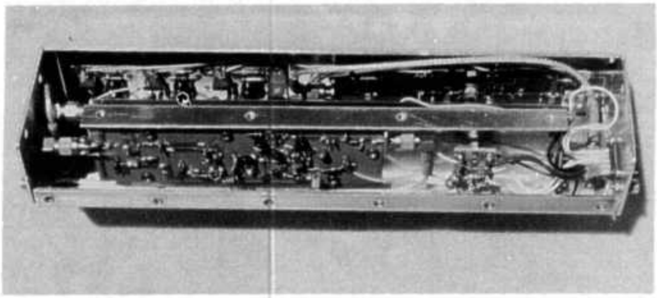

Fig 1—AMSAT Mode-S RF module.

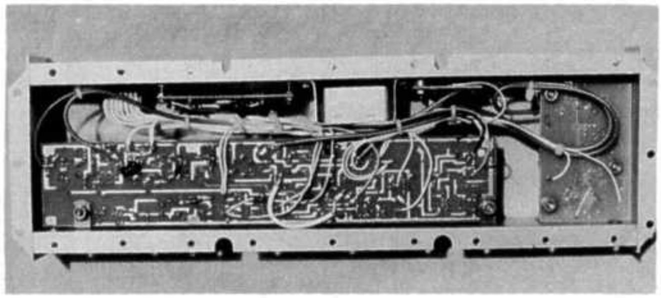

Fig 2—AMSAT Mode-S IF module.

Development Team

The development of the Mode-S transponder has been shared among many amateurs. Specific task leaders and their area of responsibility are listed below:

William McCaa, KØRZ—Project Coordination, Construction

Ray Uberecken, AAØL—S-Band Housing

Steve Ernst, WBØWED—S-Band Multiplier and Mixer

Chuck Hill, KYØS—Local Oscillators and 3X Mulitiplier

Gordon Hardman, KE3D—VHF Mixers, IF Amplifier, Control

Jan King, W3GEY—Placement, Spacecraft Interface

Chip Angle, N6CA—S-Band RF Power Amplifier

Hans Van de Groenendaal, ZS6AKV—S-Band Antenna

Bits

A Home-Built Frequency Synthesizer for 45 to 75 MHz

An article bearing the same name appeared in the Radio Society of Great Britain's August 1986 *RadCom*. In amateur circles, there is some debate as to whether a frequency synthesizer be used in place of a VFO in HF equipment. To pursuade other amateurs, author John Crawley, GM3LBX, built one unit from readily available European parts. His circuit is used as the heart of an upconverting transceiver to cover 100 kHz to 30 MHz.

Part 1 of Crawley's two-part article contains information on how the system was developed, the tuning and control circuit and necessary schematics. Part 2 will be published in a successive issue. *—KA1DYZ*

The No Ditter

As an OSCAR enthusiast, the following scenario may be familiar: Another operator is sending a series of dits across the space bands and through the middle of your QSO to listen for their own signal to come back through the satellite. How can this interference be minimized? Called the No Ditter, this small, but useful device is made simply by tacking two different-sized circular discs together. Each disc has its own frequency listing around the edges, one for the transmitter, the other for the receiver. By matching the two numbers, the operator, who then hears a signal on another OSCAR frequency, can reference the wheel to learn what frequency he or she can tune to on their transmitter to QSO with the other operator. By doing so, the step of dit dahing your way to the next frequency is eliminated. This makes everyone happy.

The No Ditter is available in several varieties: AMSAT-OSCAR 10 and JO12 (formerly JAS-1). Prices are $3 ppd for AO10 and $4 ppd for JO12. Write to Dave Guimont, WB6LLO, 5030 July St, San Diego, CA 92110; tel (619)275-1495. *—KA1DYZ*

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- Freon TMS Solvent—for PC boards and photocopy equipment
- Contact Re-Nu—clean relays, tuners, shaft encoders and switching devices
- Connector Cleaner—cleans, protects and lubricates
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>50
Focus on technology above 50 MHz

By Bill Olson, W3HQT
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Burnham, ME 04922

Test Equipment for the VHF/UHF and Microwave Experimenter

How many times have you read a construction article for a high-frequency, solid-state piece of gear that ended with a statement saying that the unit *must* be tested with a spectrum analyzer? This is great for those who work where there is such gear, but a good many VHF/UHF equipment builders are discouraged because they have no way of testing the stuff. The situation seems even more hopeless when you hear someone talking about taking his new 1296 whizbang into work and tweaking it up on a new $50,000 spectrum analyzer. It is true that testing equipment for use above 500 MHz becomes a bit more tricky than at "dc" and that testing solid-state equipment is tricky at any frequency. But don't give up hope! Test-equipment technology is moving along at a fast rate, so equipment that was state of the art a few years ago is showing up at flea markets and surplus outlets in great quantities.

The RF test equipment we most often require comes in three basic categories:

1) Power (both absolute and power gain).
2) Frequency (both quantity and quality).
3) Noise figure.

In addition, many of us would like to do antenna-gain and pattern measurements, which are really just a special case of power measurement. This month and next I will give you a brief description of what equipment to look for and show you how to use it.

Power Measurement

In many ham shacks, the Bird model 43 Thruline Wattmeter is the most sophisticated piece of test equipment. The model 43 is an excellent piece of gear and is accurate enough for most measurements. Limitations are that it is a relatively narrowband instrument and the elements are quite expensive, especially for frequencies above 1 GHz and power levels below 1 W. For measurement in the milliwatt range, it is all but useless.

When used with the proper element, the directivity— the indication of reflected power when measuring forward power and vice-versa—is in the vicinity of 30 dB, which is good. Beware when using elements outside their specified frequency range (for example, measuring 1296-MHz power with a 400- to 1000-MHz element), however. While the forward measurement might still be reasonably accurate, the reflected reading may be mostly *forward* power! Still the venerable Bird 43 is an excellent value and often found at a reasonable price.

For low-power and high-frequency measurements, the best bet is to obtain a low-power *microwave power meter* and some calibrated attenuators. These instruments use a sensitive thermistor or diode power sensor in conjunction with an accurate ac voltmeter in a bridge circuit. The most common power sensor, often known as a *bolometer*, contains a 50-ohm load resistor thermally coupled to a thermistor. As the load resistor heats up with applied power, so does the thermistor. As the thermistor changes resistance, the meter circuitry converts the resistance into a power reading. Since the unit is basically reading power as heat in the load resistor, the upper frequency limit is limited only by the SWR of the load resistor. The lower frequency limit is nearly dc.

Most microwave power meters can be used in from the microwatt range up to 10 mW or so. To measure higher power, calibrated attenuators can be inserted between the power sensor and the RF source to be measured. These instruments are excellent for tuning up local oscillators and low-power transmit stages. With outboard attenuators, they can be used at any power level an amateur is likely to encounter.

If you look around, there are some excellent older power meters available on the surplus market. For example, the Hewlett Packard model 430C microwave power meter, in conjunction with the HP 477B thermistor mount, will measure power levels from 0.02 mW to 10 mW at frequencies from 10 MHz to 10 GHz. I have seen HP 430Cs at flea markets for $5. While the thermistor mounts are harder to find, probably because they *can* be blown up, they can often be found in the $30 range. Later versions of this instrument, the 431, 432, 435 and 436, are improved models with temperature-compensated power sensors, lower and higher power scales, higher accuracy, digital readout and so forth. Of course, there are similar instruments from other manufacturers that show up at flea markets and surplus outlets as well.

The main caution when buying a power meter of this type is to determine that the power sensor is good. If you can not try the meter out ahead of time, at least measure the input to the thermistor mount with a good ohmmeter. It should be 50 ohms. Power attenuators, also common at flea markets, should be tested as well since they can be destroyed by higher-than-rated power levels.

The power meters mentioned above are meant to terminate a line, as shown in Figs 1A and 1B. They can be used for inline measurements in conjunction with a directional coupler. Directional couplers are specified for coupling factor and frequency range, for example 20 dB from 1.0 to 2.0 GHz. See Fig 1C.

Power gain (or loss) measurement is quite simple using the setup shown in Fig 1 as long as the power levels are within the range of the equipment. Measuring "small signal" gain (such as that of a receiving preamp) should be done at the lowest possible level. Sometimes high-level inputs (not high enough to saturate the amplifier) will mask low-level oscillations that occur at normal input levels.

Frequency Measurement

Frequency measurements can be divided into two areas: quantity and quality. Quantitative measurements are normally made these days with frequency counters. There are a number of new, inexpensive, fairly accurate counters available with upper frequency limits of 500 or 600 MHz. A few work up to over 1300 MHz. Such counters are useful for setting local oscillators on frequency or determining transmitter frequency, but do nothing to tell you about spurious signals. They just count pulses per second and convert that number to frequency.

Most solid-state equipment is prone to spurious oscillation. This is because the transistors used have very high gain at low frequencies. In addition, modern microstrip techniques, especially at UHF and above, tend to present multiple feedback paths that can cause oscillations at or near the desired frequency of operation.

How do we look at a signal to determine its cleanliness? One way is to put it on the air and get a citation from the FCC. Another is to give it to a friend to take in to work and test on his HP 8565A spectrum analyzer. What if you don't have such a friend or you live in Maine? Suppose the piece of gear is large and has an attached 500-pound power supply with an external 50-A Variac? Obviously, if you want to do the job right you have to get the right tools. The right tool in this case is a spectrum analyzer.

A spectrum analyzer in its simplest form is just an electronically-swept superhet receiver with the output coupled to an oscilloscope that reads amplitude versus frequency. Fig 2 shows a typical test setup for testing power and power gain with additional coupling to a spectrum analyzer.

It is true that the modern state-of-the-art analyzers are *very* expensive, but it's also true that they have more features and functions than we would ever need in the ham shack. Since most of the measurements we need to make are qualitative, such as checking for spurious responses, or rough quantitative, such as checking the approximate suppression level of harmonics or spurs, an older model is perfectly adequate.

These units are beginning to show up on the surplus market in ever-increasing quantities. Some are boat anchors to be sure, but they work. Once the crane drops it down in the basement. . . The Army TS-1010/UPM84, for example, covers 10 MHz to 44 GHz in eight bands, uses a klystron sweep oscillator, weighs about 150 pounds and has sold for under $300 in working condition.

A more recent model of the same ilk is the HP 851B/8551B. This instrument is two generations old and uses a backwards wave oscillator (BWO) in the sweep generator. Some of the later versions of this scope were transistorized in all but a few of the high-frequency amplifier stages and are quite reliable. A word of caution: If the unit does not work, the BWO may be gone. This is definitely not something you find down at Radio Shack.

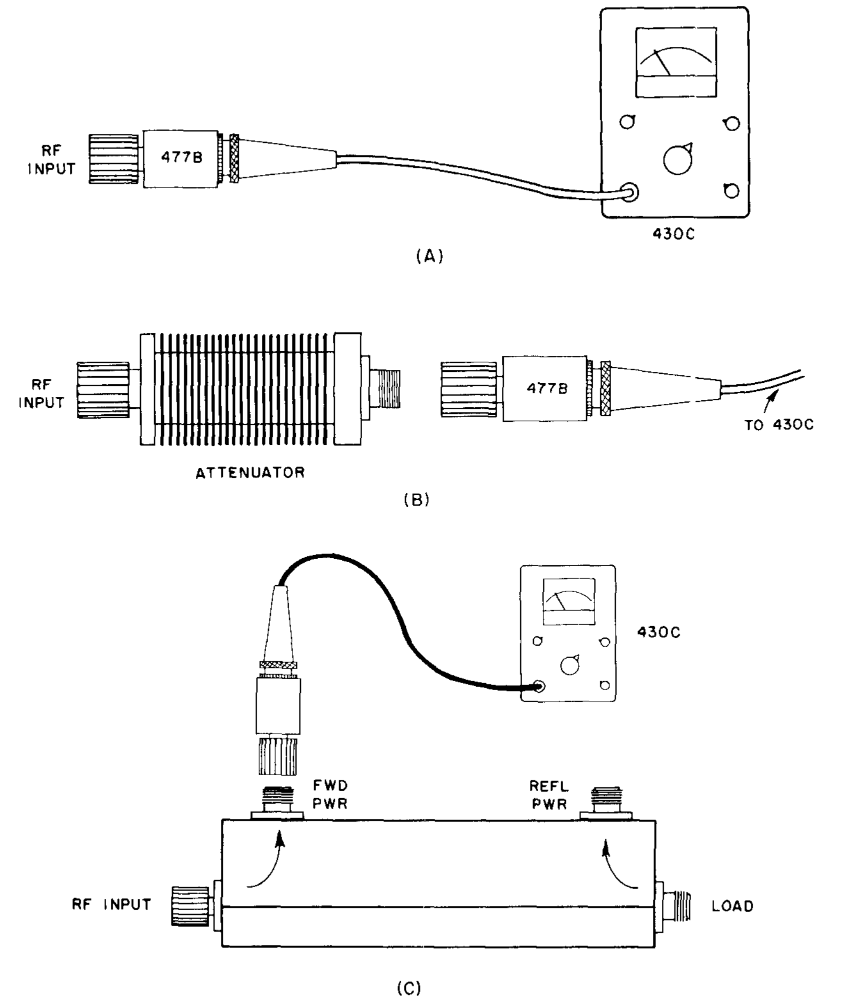

Fig 1—The setup at A is for low-power (up to 10 mW) measurements using the HP 430C/477B or equivalent. For higher-power measurements, an attenuator must be added as shown at B. A directional coupler like that shown at C is necessary for inline measurements of forward or reflected power.

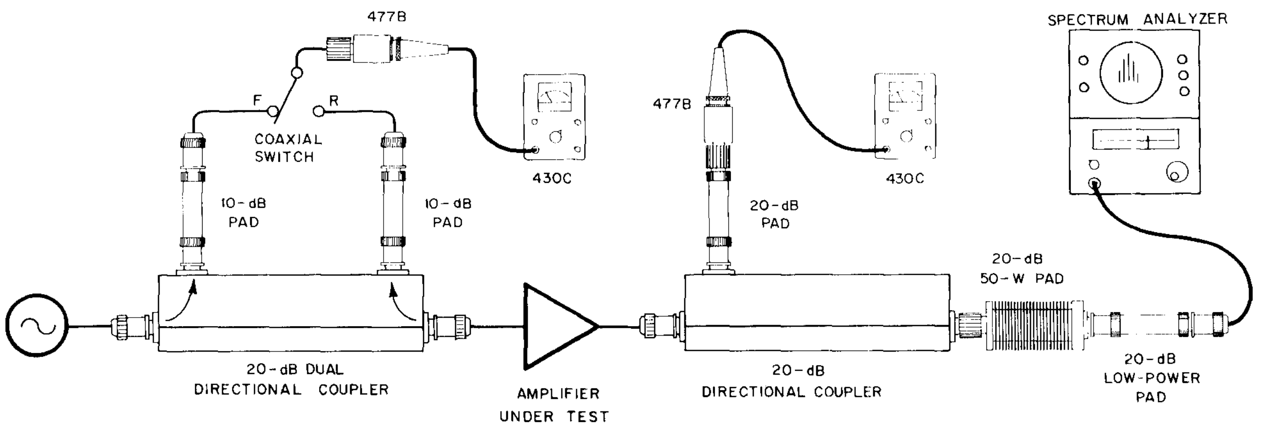

Fig 2—A typical amateur test setup might look like this. Input forward and reflected power are read using a dual directional coupler and a power meter. Output power is measured with a directional coupler and a power meter. The spectrum analyzer is connected to the output of the amplifier under test, rather than to the 20-dB tap of a directional coupler. Here, a relatively flat frequency response is desirable because the spectrum analyzer is used to look at harmonics or low-frequency spurs outside the range of the directional coupler. It is very important to use the correct attenuators when coupling to test equipment. Signal levels in excess of the maximum rated input power can easily damage sensitive power meters or spectrum-analyzer front ends.

Stay clear. . . The surplus-market price for a working HP 851B/8551B is under $1000 and going down.

Other units to be on the lookout for are the spectrum analyzer plug-ins for the Tektronix 530, 540 and 550 series scope mainframes. The Tektronix 1L20 covers 10 MHz to 4.2 GHz, uses a solid state sweep oscillator, and is often available for under $500.

While I don't expect everyone to run right out and put together a test setup like the one described here, at least it's *possible*, and we can all be on the lookout for these bargain pieces of equipment. Next month I will discuss noise figure measurement and antenna gain measurement briefly and describe how to get reasonably good measurements in these areas with a modest investment.

Bits

Build an OSCAR-10 PSK Decoder and Receive Telemetry

Prior to OSCAR 10's near miss with death, satellite users could receive telemetry by CW, RTTY or PSK. However, during the satellite emergency, PSK was the only method available for receiving OSCAR 10 data. The information presented here offers background data on the PSK modulator, what I have learned about it and how you can also receive PSK data.

The demodulator I built was designed by James Miller, G3RUH. An article about his unit was first published in *Electronics and Wireless World* and later in *Ham Radio*.[1,2] Other than the G3RUH unit, Japan's Osamu Yamamoto, JA1TUR, developed a demodulator, while AMSAT-DL developed a unit of their own. Information on the AMSAT-DL demodulator is available as part of a series of ASCII files about Phase 3C's RUDAK transponder.[3]

If you are interested in building the G3RUH demodulator, Radio Kit sells a semi-kit.[4] The semi-kit contains most of the demodulator parts, but the mounting hardware, power supply, knobs and plugs/sockets for power and data output must be obtained separately. You will also need to physically punch the panel holes and label the controls. A circuit board can be purchased from AMSAT-UK; all the parts except for a few ICs can be purchased at Radio Shack or from Dick Smith Electronics.[5,6]

Construction of the demodulator is not difficult. A soldering iron with a *fine* pencil tip is required; many of the circuit board traces are close together. If you work in a well-lighted area and work carefully, there should be little difficulty in constructing the demodulator. I found that tuning the two filters was the only task that required extra time. The capacitors and parts to properly tune the filters are available from Dick Smith Electronics.

Anyone contemplating building the G3RUH unit should first reference the two G3RUH articles. Best of all, James Miller is as close as a letter. If you have any problems building the demodulator, contact me or write to Jim (with several IRCs).

Putting the Demodulator to Work

My demodulator did not work immediately because of a small solder whisker. It was G3RUH's patience and advice that helped to correct the problem. The demodulator now works perfectly!

US builders might experience confusion about the type of demodulator output. G3RUH confirmed that the demodulator provides true RS-232-C or TTL output without additional modifications. If you need more information about the subject, drop me a note with an SASE. Finally, Jim has provided the necessary changes to the AO-10 demodulator to enable users to receive the FO-12 satellite.

At my station, I use the G3RUH demodulator with a TS-700A transceiver, dual KLM 14C antennas and a Commodore 64™ computer that has an MFJ RS-232-C board on the user port. I wired my AO-10 demodulator for true RS-232-C output so that I could use the same decoder on any computer with an RS-232-C port. The only additional item required to decode the PSK data is a *terminal program*. The same terminal program that you use to send programs over the telephone can be used with the AO-10 decoder to receive the ASCII information.

If you are interested in receiving the AO-10 PSK data, reference the *OSCAR-10 Handbook*; it is available from AMSAT-UK.[7] This book is different from the Project OSCAR version and includes a discussion on the make up of the OSCAR-10 data blocks.

Data Blocks

PSK data is sent in blocks of 512 bytes. Each block has a letter to identify it. OSCAR-10 blocks are identified as M, N, Q or Y. The M, N and Y blocks are sent in ASCII format. The terminal program used with the G3RUH decoder allows you to view this information on your display. M and N blocks are text messages similar to those sent between command stations or like W1AW bulletins that are received on RTTY or CW.

The Q block is difficult to receive because it is sent in both the ASCII and hex format. Essentially, the Q block is internal telemetry samples from some 100+ channels throughout OSCAR 10. The Y block reads the same channels of data you see on the RTTY data.

To receive PSK information, I use the arrangement mentioned plus a terminal program. That is *all* I need to copy the ASCII information on the PSK data. My first attempt to copy the PSK data was 50% successful. I thought my system had more noise than was necessary. However, G. R. Ratcliff, VK5AGR, editor of the AMSAT-VK newsletter, suggests that stations near him were getting good results with a different program. On VK5AGR's advice, I changed my terminal program to use the "Plus/Term" program featured in the Feb 1985 issue of *Compute*.

Conclusion

Having been a satellite user since OSCAR 6, I have been satisfied with the results of what I've learned since working on the PSK demodulator. Not only did I learn about construction techniques and computers, but I have met several great personalities on OSCAR and have managed to get a better feel for what the satellite is doing. If you consider building the G3RUH demodulator, you won't be disappointd. Best of all, it will work with Phase 3C!—*Ross Forbes, WB6GFJ, PO Box 1, Los Altos, CA 94023-0001*

Notes

[1]J. Miller, "Data Decoder for UoSAT," *Electronics and Wireless World*, vol 89, no. 1568, May 1983, p 28.

[2]J. Miller, "A PSK Telemetry Demodulator for OSCAR 10," *Ham Radio*, April 1985, p 50.

[3]Gary Nakayama, KH6JRB, 360 11th Ave, San Francisco, CA 94118.

[4]Radio Kit, PO Box 411, Greenville, NH 03048; tel (603)878-1033.

[5]AMSAT-UK, London, E12 5EQ, England.

[6]Dick Smith Electronics, Inc, PO Box 8021, Redwood City, CA 94063; tel 1-800-332-5373.

[7]The *OSCAR-10 Handbook* is available from R. J. C. Broadbent, G3AAJ, Honorary Sec/Treas AMSAT-UK, 94 Herongate Rd, Wanstead Park, London, E12 5EQ, England.

Intellectual Properties

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Exploiting Your Mousetrap

"If a man can write a better book, preach a better sermon or make a better mousetrap than his neighbor, though he builds his house in the woods, the world will make a beaten path to his door."
Attributed to Ralph Waldo Emerson, 1889

This adage may have been true 97 years ago, but today it is in need of modification. Today the maker of a better mousetrap must clear the path *himself* before the world can find his door. This month's column takes a look at how to clear the path and what pitfalls to avoid.

The Problem

For purposes of illustration, let's imagine Jim Q. Ham's better mousetrap is a microprocessor-based system called the "Speech Sender." The unit connects to the key jack of a transmitter to convert speech into corresponding CW signals. In combination with CW readers already available on the market, the Speech Sender allows anyone who can speak and read to converse at virtually any speed in perfect CW.

Jim sees a potential market for his device among a variety of users: SSB operators who would like to make CW contacts, but are uncomfortable with keyers and keyboards, handicapped amateurs who are manually impaired, and the ever-prevalent ham gadgeteer. Jim's problem is that he has neither the time, the money nor the marketing ability needed to commercially exploit his device properly. What does he do?

The Gutsy Approach

There are basically two approaches to Jim's dilemma. The first is to find the requisite time, money and marketing talent required to do the job himself. This solution generally entails Jim's quitting his regular job, finding a few hundred thousand dollars of seed capital, forming a company and hiring corporate officers who've done this sort of thing before.

Jim may, as do many others, question the need for a six-figure initial investment. He might look at his cost of producing the Speech Sender and the cost of setting up a small office and estimate that he can get started with an investment of ten thousand dollars or so. He's right. He can start with this amount, but the actual hurdle is to keep the business going.

The overwhelming cause of failure for start-up businesses is undercapitalization. One handy rule of thumb is that a start-up business producing a single innovative product should plan on a product lifetime of less than a year. Thus, if Jim decides to start his own business, it should be financed and run so that the Speech Sender is fully exploited within a year after introduction and so that the company has made sufficient profit within this period to make the venture worthwhile.

(The one year period is a "guesstimate" of how long it will take the industry giants to recognize the profitability of the Speech Sender, copy it, improve it and sell it for less than Jim's product so as to overtake his position in the market. If Jim is able to obtain patent protection on his device or, if his device is so well received in the market that it becomes the de facto standard, then the product lifetime may be substantially longer than the one-year period. However, for planning purposes, it is generally best to anticipate Murphy and not to rely on serendipity.)

If the one-year product lifetime is accepted, then the necessity for six figure capitalization becomes more apparent. The bulk of the money is not for product cost or personnel, but rather for penetrating and saturating the market within a short time period. Full-page, full-color ads in the ham magazines aren't inexpensive. If, after the one- year period, the product continues to be a commercial success, Jim can consider the resulting revenue to be a bonus.

Finding a six-figure seed capital investment may be the toughest part of Jim's venture. Commercial seed capitalists are one option. An added benefit of choosing them is that many offer experienced management and marketing advice. Other options include personally financing the venture, finding an "angel" (typically a well-to-do friend or relative) or qualifying for government funds. (In Oregon, a portion of the state lottery revenue is earmarked for funding selected start-up ventures in amounts ranging up to $250,000). Each of these sources, however, is difficult to tap.

Although the do-it-yourself approach offers the highest potential rewards, it also presents the highest risk. Few of us have the fortitude and the strong stomachs needed to make it work. More attractive to the risk averse is the second approach: Sell the idea to a company that is already well poised to exploit it.

The Risk Averse Approach

The concept of selling the Speech Sender's rights to a ham manufacturer sounds simple, but it is usually just the opposite. Jim's wish list is reasonable: He wants to disclose the details of the device to the manufacturer with the understanding that they will keep it secret or, if used, that they will pay Jim a royalty on any units produced.

Although Jim's list is reasonable, the manufacturer has at least two important reasons for avoiding such a deal. First, the manufacturer may already know of suitable voice-to-CW conversion technology, or may have such a system under development. Jim's proposed deal might legally oblige the manufacturer to pay him royalty payments even though the technology was actually obtained, or was being developed, independently.

The second reason for the manufacturer to refuse Jim's proposal is that it may oblige the manufacturer to pay for something that its competitors can use freely. This is often the case where an invention such as Jim's is not patentable and the technology is discoverable from an inspection of the unit itself. As soon as the manufacturer introduces the product, its competitors can copy and sell the same product for less—they have no obligation to pay royalties.

In this situation, Jim, like others in a similar position, does not have much bargaining power. He essentially is faced with the prospect of accepting whatever terms the manufacturer offers him. These terms often can be summarized as follows:

1. The manufacturer has no obligation to use the device or concept, nor to keep it secret.
2. If the device is not patented and the manufacturer wishes to use it, Jim will be paid an amount of money determined solely by the manufacturer. This amount may only be nominal.
3. If the device is patented and the manufacturer wishes to use it, the manufacturer will negotiate for the rights to make, use and/or sell the device.

To better his chances of striking a favorable deal, Jim may inquire of several manufacturers as to their idea submission policies and may pursue a relationship with the company having the most favorable policy.

If the Speech Sender is unpatentable, but likely to yield significant commercial advantage to the first manufacturer offering it for sale, then Jim and his attorney may try to negotiate a more favorable agreement than that initally proposed by the manufacturer. Small- and medium-size companies can sometimes be persuaded to work out a compromise agreement if they are convinced of the potential importance of the device being offered. Such a compromise agreement should provide a balance between Jim's desire for compensation and the company's desire to avoid competitive disadvantage.

In his survey of the idea submission policies of various manufacturers, Jim may find some who absolutely will not review outside submissions. Such policies can generally be traced to either the NIH (Not-Invented-Here) syndrome or to paranoia of legal liability.

The NIH syndrome is prevalent at some large companies that employ engineers dedicated to product development. Such companies reason that if the product was not invented by their in-house specialists, then it is not of interest to the company. (Besides, if an important product is received from outside the company it may mock the quality of, and question the investment in, the internal product development staff.)

Paranoia of legal liability is the other principal reason some companies do not consider outside submissions. There are horror stories in the industry about companies that have taken outside ideas and turned them into successful commercial products. The outside inventor then sues the company, trying to get paid more than he originally bargained for. Such a case against Sears Robuck involving a quick release feature for a socket wrench resulted in a multi-million dollar judgment in favor of the plaintiff. In view of such potential liability, some companies have decided to skip this risk entirely by foregoing opportunities to exploit product ideas submitted by outside inventors.

Invention Promotion Companies

For completeness, it should be noted that Jim has the option of submitting the Speech Sender to one of several invention promotion companies. Such companies often advertise in the classified ads of widely circulated magazines and in many Yellow Page books, offering to conduct patentability searches and to try and find an interested corporate manufacturer, all for a substantial fee. If Jim wants to consider this alternative, he'd be well advised to carefully check the promoter's track record, both in the particular technology involved and with the Better Business Bureau.

Give It Away

A third option, not considered by some inventors, is to publicly disclose the details of the device so that the public might benefit by its availability. This is the philosophy of most *QST* authors.

An interesting variation on this theme recently occurred in a case involving Ron Raikes, WA8DED. Ron wrote a control program for a packet radio terminal node and intended that it be distributed free of charge for nonprofit, noncommercial amateur use. Heathkit understood that the software, although copyrighted, was in the public domain and sought to help Ron distribute it by providing the software, without cost, to customers that bought Heath's terminal node controller. Ron felt that this Heath activity did not fit the bill of a nonprofit organization and requested a royalty for copies distributed. Heath obliged by compensating Ron for copies already distributed and by agreeing not to distribute the software further.

Conclusion

Jim has several options for exploiting his better mousetrap, but none offer the quick fame and fortune he may have hoped for. If it's any consolation, quick fame and fortune didn't come to Edison or DeForest either. Both worked tirelessly for years and exploited their inventions themselves before establishing their places in history. Jim's results, too, will likely be proportional to the amount of effort he puts into clearing the path to his door.

Bits

Amateur 902-928 MHz Limitations Clarified

The FCC has clarified certain frequency privileges and power limitations imposed on use of the 902 to 928-MHz frequency band by Amateur Radio operators. The action partially granted a petition for reconsideration filed by David B. Popkin.

Specifically, the FCC amended Sec 97.67(i) of the rules to clarify that while no amateur station transmissions are permitted on 902-928 MHz within 150 miles of the White Sands Missile Range, reduced power transmissions (at 50-W peak envelope output power) are permitted between 150 and 200 miles from the boundaries of the Range. The FCC also ammended Secs 97.7(g)(8) and (9) to clarify that secondary status bears no relation to the areas of prohibited operation for the 902 to 928-MHz band. Additionally, the FCC clarified that pulse emissions by amateur stations are permitted in this same frequency band.

These rules became effective October 4, 1986. For further information, contact John Borkowski at (202)632-4964.—*FCC*

A Dream Come True

How many times have you set out to build a circuit, but wished you could reference a similar one for ideas? RCA offers a broad and varied line of linear integrated circuits and discrete MOSFETs. Putting these devices to work, the company came up with a booklet entitled, *Circuit Ideas for Linear ICs* and shows 102 practical circuits. Design ideas include circuits for timing, frequency generation, frequency division, measurement, amplifier, comparator, data conversion/display circuits, alarm and monitoring circuits, and so on. For a copy of the booklet, write to RCA Solid State, Route 202, Somerville, NJ 08876.—*KA1DYZ*