Slow Scan TV - It Isn't Expensive Anymore!

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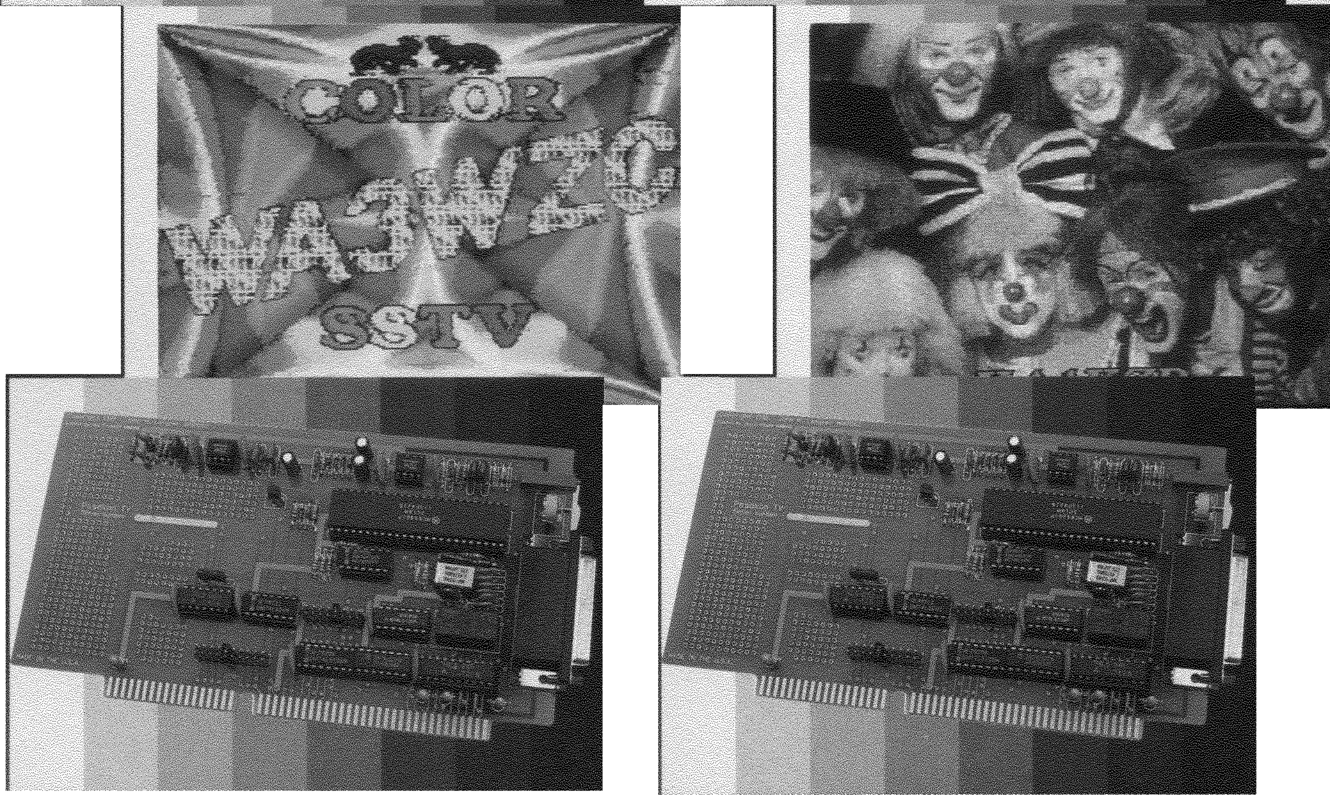


SLOW-SCAN TV—

Ham stations equipped with an IBM PC-compatible computer now have another use for it — *SSTV!* With this plug-in board, you've got most of the makings of a superb SSTV station!

By John Langner, WB2OSZ 115 Stedman St #Q Chelmsford, MA 01824-1823

Most hams who have an interest in operating slow-scan television (SSTV) are often scared by the enduring myth that it's expensive. As outmoded as this tale is, it does have basis in fact. A few years ago, the most popular piece of SSTV equipment was the Robot 1200C scan converter.[1] It's a great product, but its $1300 price tag and the lack of any viable less-expensive alternative severely restricted the widespread use of SSTV.

Now, for the price of a '1200C, you can buy a blazingly fast home computer complete with floppy disk drives, a good-sized hard disk, VGA color monitor and video card, at least a megabyte of RAM, and still have enough left over for an SSTV interface and software. For most hams, this is the only *sensible* approach!

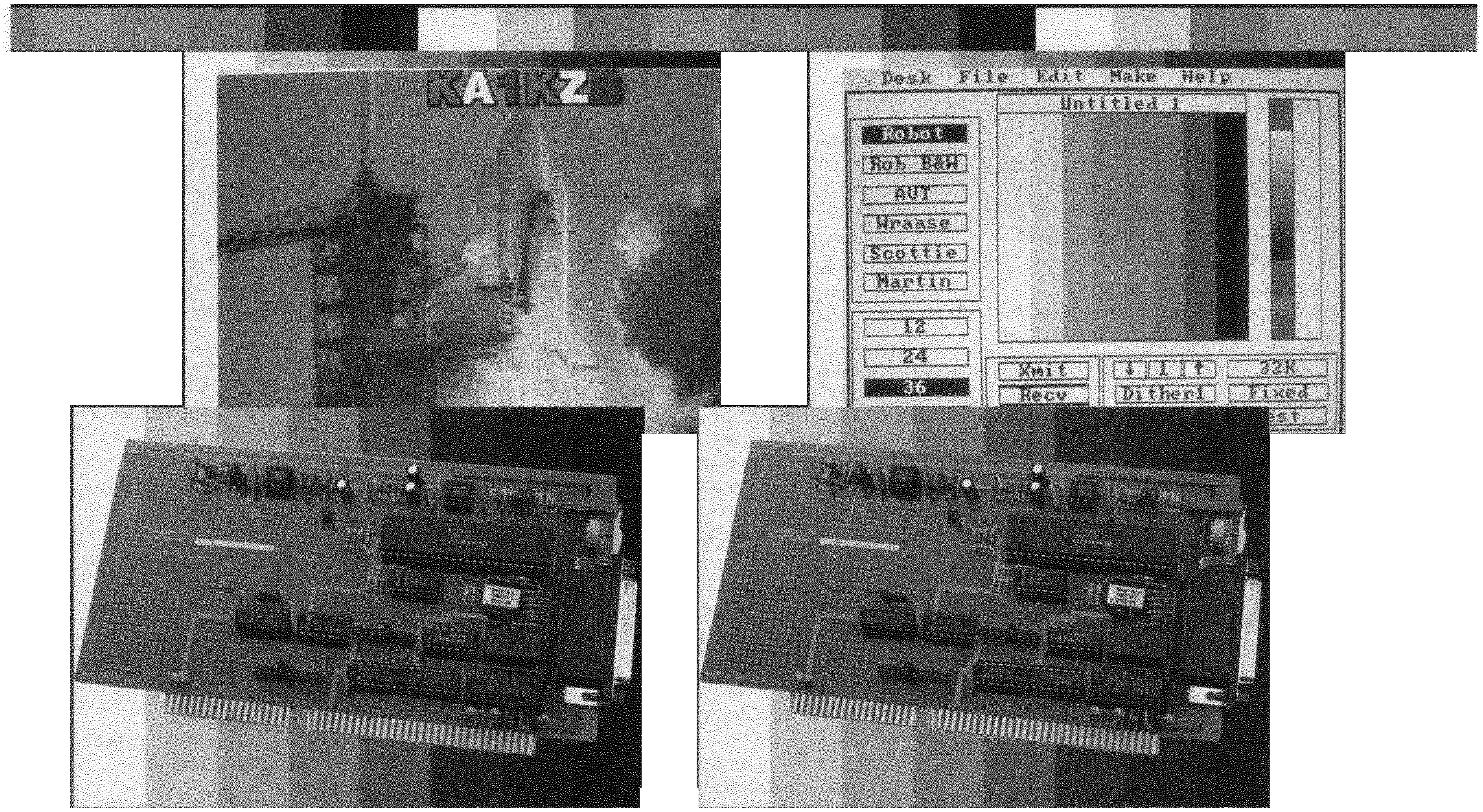
A couple of years ago, comprehensive color SSTV systems became available for use with Amiga and Atari ST computers.[2, 3] Both of these systems support a wide variety of transmission modes: Robot, AVT,[4] Martin, Scottie, Wraase[5] (you'll find a Glossary of Terms in Table 1), graphical user interfaces, on-screen tuning indicators, the ability to read and write popular image-file formats and modify received images. Surprisingly, nothing comparable was available for the ubiquitous IBM PC! SSTV home-brewers are nearly extinct, so I figured if *I* didn't do it, it wouldn't get done! As a result, a comprehensive, easy-to-use, low-cost color SSTV system is now available[6] for use with a VGA-equipped IBM PC/AT-compatible.

In this article, I'll provide some background on SSTV, a few tips for home-brewers and the details of my latest project called *Pasokon TV*. (*Pasokon*—pronounced "pah-so-cone"—is the Japanese abbreviation for *personal computer.*) See Table 2 for its specifications.

Some SSTV History

Amateur slow-scan TV began in 1958, when a group of experimenters, organized by Copthorne MacDonald (then WA2BCW, now VY2CM) became interested in sending images on the MF/HF bands.[7] Trouble was, a standard commercial TV signal requires a bandwidth of a few *megahertz*, but signals in the MF/HF amateur bands are restricted to

[1]Notes appear on page 30.



IT ISN'T EXPENSIVE ANYMORE!

bandwidths of a few *kilohertz*. Clearly, it wasn't possible to squeeze thirty 525-line images per second into such a narrow bandwidth. Another standard was needed.

The early SSTV 8-second transmission standard is illustrated in Fig 1. Audio tones in the 1500- to 2300-Hz range represent black, white and shades of gray. A short, 1200-Hz burst separates the scan lines, and a longer, 1200-Hz tone signals the beginning of a new frame.

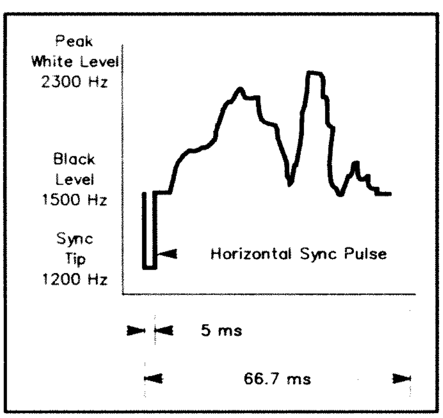


Fig 1—Original 8-second black-and-white transmission format showing the video-signal levels for peak white, black and sync (commonly referred to as "blacker than black"). This transmission mode uses a total of 120 lines transmitted at 15 lines per second for a total transmission time of 8 seconds. The durations of the horizontal and vertical sync pulses are 5 and 30 ms, respectively.

Hams have always been very creative about taking junk and turning it into useful radio equipment. In this case, the early SSTVers located some surplus radar display tubes. These are similar to the CRTs used in oscilloscopes or TV sets, with one important difference: They have a very-long-persistence (P7) phosphor. This means that a spot on the screen continues to glow for *several seconds* after the electron beam has passed that point. By using these long-persistence tubes, the beginning of the image was still visible, though somewhat faded, at the end of the 8-second transmission—but the complete picture could be seen!

Early Color SSTV

Sending color pictures with black-and-white (B&W) equipment was a real challenge! The sender would transmit the same picture three times, each time with a red, green, or blue filter in front of the TV camera lens (see Fig 2). The receiving operator took three long-exposure photographs of the screen, placing red, green and blue filters in front of the film camera's lens at the appropriate times. This is known as *frame-sequential* color SSTV. Fig 3 illustrates the signals sent for a color-bar test pattern.

In the mid 1970s, it became feasible to save these three images in solid-state memory and simultaneously display them on a color TV. But, the frame-sequential method had some problems. As the first frame was received, you'd see a red and black image. During the second frame, green and yellow would appear. Blue, white, and other colors didn't show up until the final frame. Any noise (QRM or QRN) could ruin the image registration (the overlay of the frames) and spoil the picture.

The next step forward was the *line-sequential* method. As shown in Fig 4, each line is scanned three times: once each for the red, green and blue picture components. Pictures could be seen in full color as they were received and registration problems were reduced. The Martin, Scottie, and Wraase modes are all minor variations of the line-sequential theme.

Rather than sending color images with the usual RGB components, Robot Research used luminance and chrominance signals for the 1200C modes.[8] The first half or two-thirds of each scan line contained the luminance information, which is a weighted average of the R, G and B components. The last half or one-third of each line contained the chrominance signal with the color infor-

Table 1
Glossary

ATV—Amateur Television. Sending pictures by Amateur Radio. You'd expect this abbreviation to apply equally to fast-scan television (FSTV), slow-scan television (SSTV) and facsimile (fax), but it's generally applied only to FSTV.

AVT—Amiga Video Transceiver.
1) Interface and software for use with an Amiga computer, developed by Ben Blish-Williams, AA7AS, and manufactured by Advanced Electronic Applications (AEA);
2) a family of transmission modes first introduced with the AVT product.

Back porch—The blank part of a scan line immediately following the horizontal sync pulse.

Chrominance—The color component of a video signal. NTSC and PAL transmit color images as a black-and-white compatible luminance signal along with a color subcarrier. The subcarrier phase represents the hue and the subcarrier's amplitude is the saturation. Robot color modes transmit pixel values as luminance (Y) and chrominance (R-Y [red minus luminance] and B-Y [blue minus luminance]) rather than RGB [red, green, blue]).

Demodulator—For SSTV, a device that extracts image and sync information from an audio signal.

Field—Collection of top to bottom scan lines. When interlaced, a field does not contain adjacent scan lines and there is more than one field per frame.

Frame—One complete scanned image. The Robot 36-second color mode has 240 lines per frame. NTSC has 525 lines per frame with about 483 usable after subtracting vertical sync and a few lines at the top containing various information.

Frame Sequential—A method of color SSTV transmission which sent complete, sequential frames of red, then green and blue. Now obsolete.

Front porch—The blank part of a scan line just before the horizontal sync.

FSTV—Fast-Scan TV. Same as common, full-color, motion commercial broadcast TV.

Interlace—Scan line ordering other than the usual sequential top to bottom. For example, NTSC sends a field with just the even lines in 1/60 second, then a field with just the odd lines in 1/60 second. This results in a complete frame 30 times a second. AVT "QRM" mode is the only SSTV mode that uses interlacing.

Line Sequential—A method of color SSTV transmission that sends red, green, and blue information for *each sequential scan line.* This approach allows full-color images to be viewed during reception.

Luminance—The brightness component of a video signal. Usually computed as Y (the luminance signal) = 0.59 G (green) + 0.30 R (red) + 0.11 B (blue).

Martin—A family of amateur SSTV transmission modes developed by Martin Emmerson, G3OQD, in England.

NTSC—National Television System Committee. Television standard used in North America and Japan.

PAL—Phase alteration line. Television standard used in Germany and many other parts of Europe.

Pixel—Picture element. The dots that make up images on a computer's monitor.

P7 monitor—SSTV display using a CRT having a very-long-persistence phosphor.

RGB—Red, Green, Blue. One of the models used to represent colors. Due to the characteristics of the human eye, most colors can be simulated by various blends of red, green, and blue light.

Robot—(1) Abbreviation for Robot 1200C scan converter; (2) a family of SSTV transmission modes introduced with the 1200C.

Scan converter—A device that converts one TV standard to another. For example, the Robot 1200C converts SSTV to and from FSTV.

Scottie—A family of amateur SSTV transmission modes developed by Eddie Murphy, GM3BSC, in Scotland.

SECAM—Sequential color and memory. Television standard used in France and the Commonwealth of Independent States.

SSTV—Slow Scan Television. Sending still images by means of audio tones on the MF/HF bands using transmission times of a few seconds to a few minutes.

Sync—That part of a TV signal that indicates the beginning of a frame (vertical sync) or the beginning of a scan line (horizontal sync).

VIS—Vertical Interval Signaling. Digital encoding of the transmission mode in the vertical sync portion of an SSTV image. This allows the receiver of a picture to automatically select the proper mode. This was introduced as part of the Robot modes and is now used by all SSTV software designers.

Wraase—A family of amateur SSTV transmission modes first introduced with the Wraase SC-1 scan converter developed by Volker Wraase, DL2RZ, of Wraase Electronik, Germany.

mation. Existing B&W equipment could display the B&W image on the first part of each scan line and the rest would go off the edge of the screen. This compatibility was very beneficial when most people still had only B&W equipment.

The luminance-chrominance encoding also made more efficient use of the transmission time. A 120-line color image could be sent in 12 seconds instead of the usual 24. Our eyes are more sensitive to details in changes of brightness than color, so the time could be used more efficiently by devoting more time to luminance than chrominance. The NTSC and PAL broadcast standards also take advantage of this characteristic of our vision and have narrower bandwidth for the color information.

The 1200C introduced another innovation of encoding the transmission mode in the vertical sync signal. By using a narrow frequency-shifted (FSK) encoding around the sync frequency, compatibility was again maintained. This new signal just looked like an extra long vertical sync to the older

Table 2
Pasokon TV Features

- Send and receive all popular modes:

Robot (color):	12, 24, 36, 72 seconds
Robot (B&W):	8, 12, 24, 36 seconds
AVT (color):	24, 90, 94, 188 seconds
Martin (color):	M1, M2, M3, M4
Scottie (color):	S1, S2, S3, S4
Wraase SC-1 (color):	24, 48, 96 seconds

- Displays full color, real-time images during receive.
- The interface PC board fits into an IBM PC-compatible computer's expansion slot.
- Automatic switching between the microphone and SSTV audio for transmit.
- Does not require a separate power supply.
- Does not interfere with printer or serial port use.
- Graphical user interface—use a mouse and/or keyboard.
- Histogram-style on-screen tuning indicator.
- Images are stored as 320 × 240 pixels with 32,768 colors.
- Displays full-screen, 256-color images on standard VGA with dithering or custom palette options.
- Displays full-screen, 32,768-color images on Super VGA cards equipped with the HiColor feature.
- Reads and writes popular image-file formats (GIF, PCX and Targa).
- Test-pattern generation.
- Image manipulation, such as zooming.
- Requires a minimum IBM PC-compatible computer configuration of an 80286 (or later) processor, 640 kbytes of RAM and a VGA display adapter.

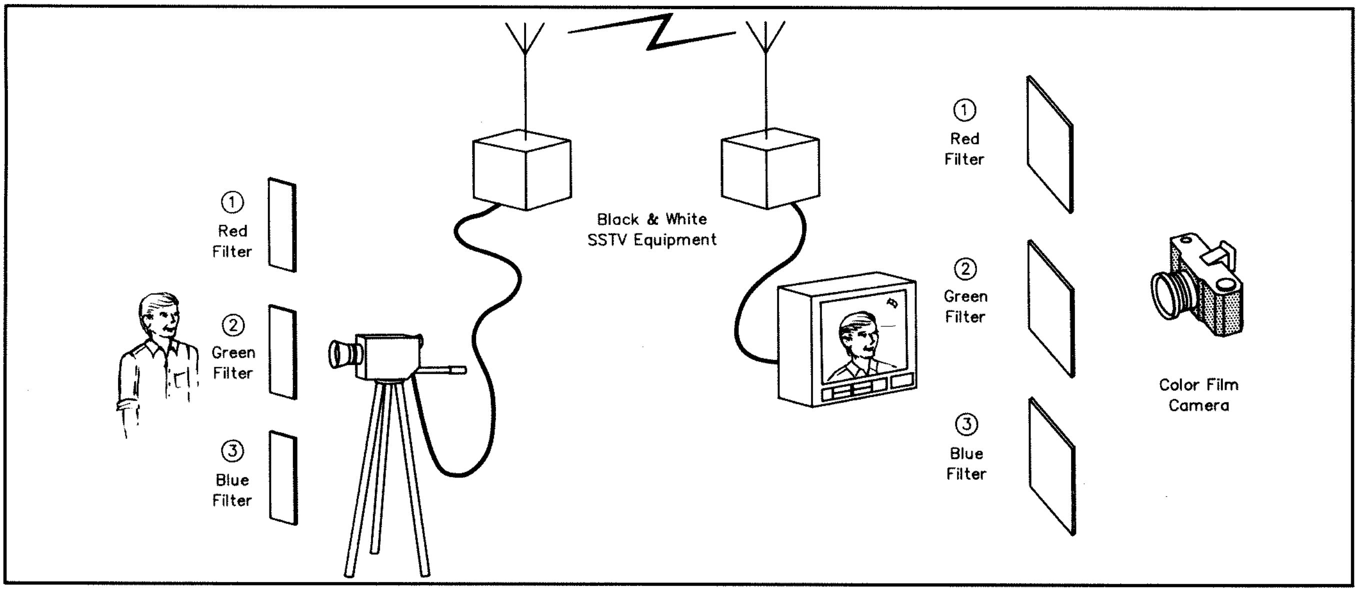


Fig 2—Early color transmission. At the transmitting end, red, green and blue filters were sequentially placed in front of the TV camera to send frame sequential signals. The receiver followed a similar procedure, taking multiple exposures of each color frame.

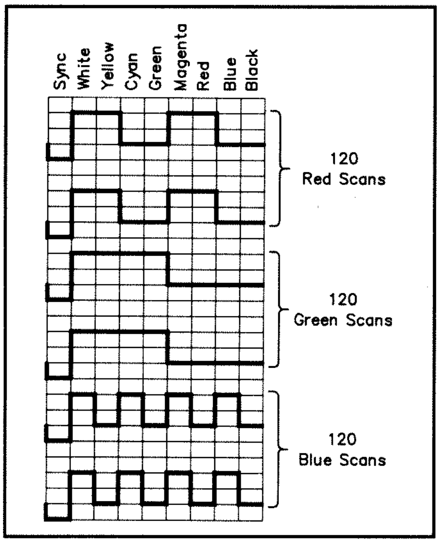


Fig 3—Waveforms of the frame-sequential color transmission employed in Fig 2, here using a color-bar test pattern.

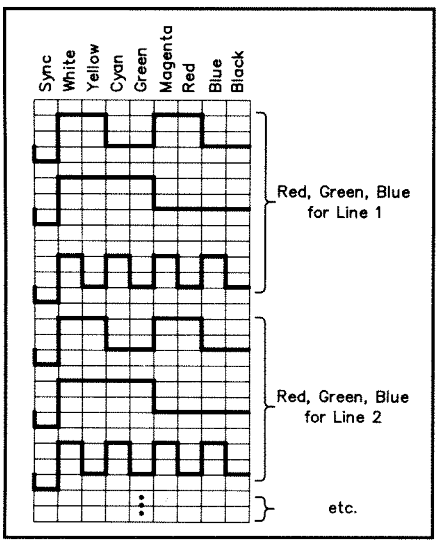


Fig 4—Line-sequential color transmission.

equipment. (See the sidebar "Examining Robot's Vertical-Interval-Signaling (VIS) Code" for more details.)

Although the Martin and Scottie modes have horizontal sync, some implementations ignore them on receive. Instead, they rely on very accurate time bases at the receiving and transmitting stations to keep in step. The advantage of this synchronous strategy is that missing or corrupted horizontal sync pulses won't disturb the received image. The disadvantage is that even slight timing inaccuracies will produce slanted pictures.

A couple of years ago, yet another incompatible mode was introduced. The *AVT* mode is different from all of the preceding in that it has *no horizontal sync!* To maintain synchronization, it relies on very accurate oscillators at the sending and receiving stations. If the beginning-of-frame signal is missed, it's all over. However, it's *much* harder to miss the 5-second AVT header than the usual 300-ms vertical sync pulse. Redundant information is encoded 32 times, and a more-powerful error-detection scheme is used. It's necessary to receive only a small part of the AVT header to achieve synchronization. After this, noise can wipe out part of the image itself, but the image alignment remains correct and the image retains the correct colors. These SSTV modes are described in more detail in several references identified in the end Notes and Bibliography. Also, see the sidebar "Popular SSTV Modes."

Examining Robot's Vertical-Interval-Signaling (VIS) Code

The original 8-second black-and-white SSTV-image standard used a 30-millisecond, 1200-Hz pulse to signal the beginning of a new frame. In the Robot 1200C, Robot Research increased the vertical sync period by a factor of 10, encoded 8 bits of digital data into it and called it *vertical-interval signaling* (VIS). VIS is composed of a start bit, 7 data bits, an even parity bit, and a stop bit, each 30 milliseconds long. (See Fig A).

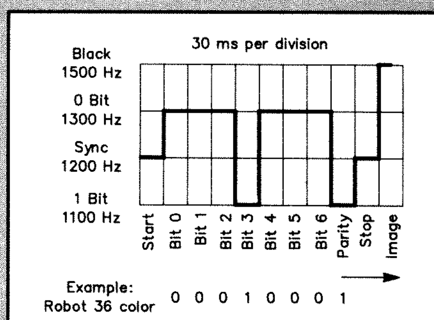


Fig A—Composition of the vertical interval signaling (VIS) code.

Since then, inventors of new SSTV modes (Martin, Scottie, AVT, etc) have adopted Robot's scheme and assigned codes to their particular mode that are unused by the Robot modes. So, each of the SSTV transmission modes has a unique VIS code. This allows new equipment to automatically select any of the new SSTV modes while maintaining compatibility with the older equipment.—*WB2OSZ*

SSTV Transmission and Reception with a Computer

Transmitting SSTV images is easy. You simply generate fairly accurate tones and change them at the proper pixel rate. Tones in the range of 1500 to 2300 Hz correspond to the pixel intensities, and most modes use a 1200-Hz tone for sync pulses. A very low-cost SSTV system can even use the computer's built-in sound generator (such as of the low-priced Ataris and Color Computers [CoCos]). *What* you transmit depends on your resources; see the sidebar "Video Digitizers."

SSTV reception is trickier. First, you must measure the frequency of the incoming audio tone. You can't simply measure the number of cycles in a second, or even 1/100 second, because the frequency is changing a couple of thousand times a second. Fig 5 illustrates one method of rapidly measuring the incoming-tone's frequency. Band-pass filters are tuned a little beyond the ends of the frequency range of interest. The output of one filter is rectified to become a positive voltage; the output of the other filter is rectified to become a negative voltage; then the voltages are summed. A low-pass filter with a cutoff frequency of about 1 kHz removes the audio-carrier ripple, while allowing the slower video signal to get through. With careful filter design, the result is a voltage that's fairly proportional to the input frequency. Finally, an analog-to-digital (A/D) converter is used to allow the computer to recognize this voltage.

Another frequency-measuring approach uses digital circuitry to measure the period of each audio cycle (see Fig 6). At a zero crossing of the signal, a counter is reset. It then proceeds to count pulses from a crystal-controlled oscillator. At the end of the audio cycle, the counter content is snatched, the

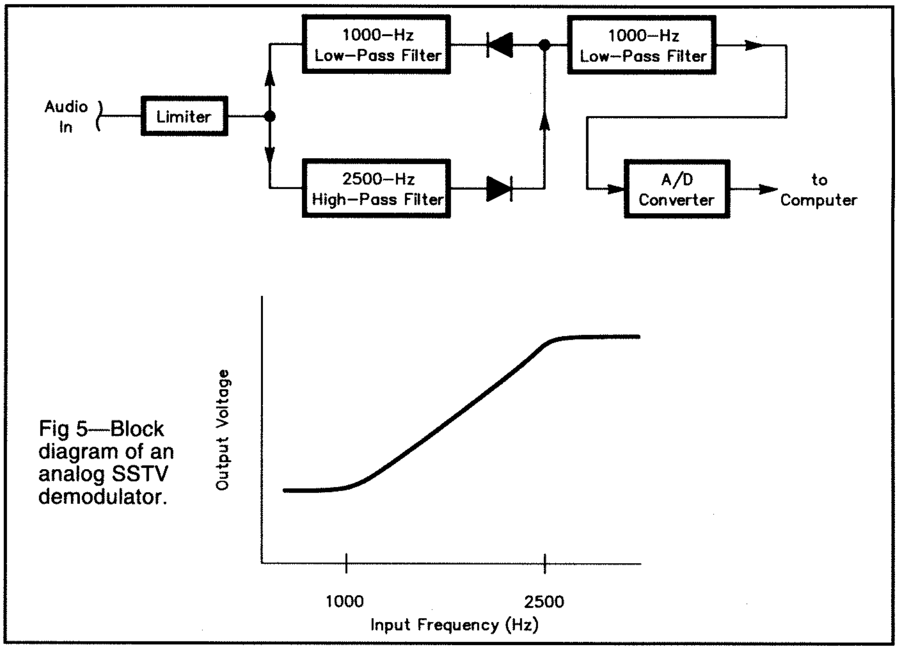


Fig 5—Block diagram of an analog SSTV demodulator.

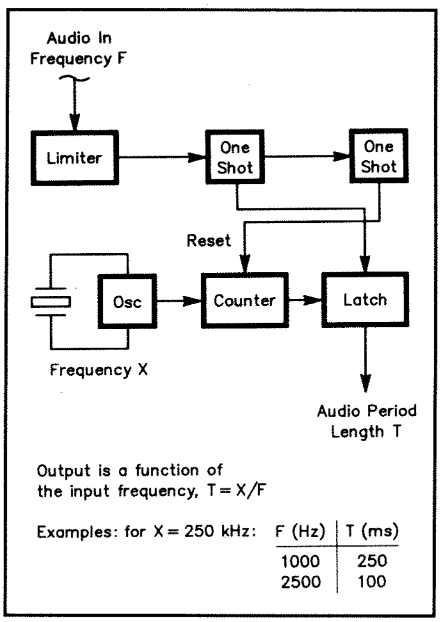


Fig 6—Block diagram of a digital SSTV demodulator.

Popular SSTV Modes

Family	*Name*	*Type*	*Time (Sec)*	*Lines*	*Notes*
Robot	8	B&W	8	120	A,E
	12	B&W	12	120	E
	24	B&W	24	240	E
	36	B&W	36	240	E
	12	Y&C	12	120	
	24	Y&C	24	120	
	36	Y&C	36	240	
	72	Y&C	72	240	
Wraase SC-1	24	RGB	24	128	C
	48	RGB	48	256	B
	96	RGB	96	256	B
Martin	M1	RGB	114	256	B
	M2	RGB	58	256	B
	M3	RGB	57	128	C
	M4	RGB	29	128	C
Scottie	S1	RGB	110	256	B
	S2	RGB	71	256	B
	S3	RGB	55	128	C
	S4	RGB	36	128	C
	DX	RGB	269	256	C
AVT	24	RGB	24	120	D
	90	RGB	90	240	D
	94	RGB	94	200	D
	188	RGB	188	400	D
	125	B&W	125	400	D

Types: B&W = Black and white.
Y&C = Color as luminance and chrominance.
RGB = Color as red, green and blue components.

Notes:
A—Very similar to the original 8-second SSTV standard.
B—The top 16 lines are always sent as gray scale, so 240 lines are usable.
C—The top 8 lines are always sent as gray scale, so 120 lines are usable.
D—AVT modes have a 5-second digital header and don't use horizontal sync.
E—The Robot 1200C doesn't actually have monochrome modes to send the luminance (Y) component of an RGB image in memory. Instead, it sends any one of the R, G, or B components.

You'll note that the number of pixels per scan line is not listed. That's because the demodulated slow-scan video is a continuously varying signal *that can be sampled at different pixel rates* depending on the implementation. Hardware-based equipment (eg, the Robot 400) used powers of two (such as 256) because they're easy to implement with hard-wired logic. Using software, it's just as easy to use any other number. Pasokon TV uses 320 pixels per line to get the proper aspect ratio with a VGA display.—*WB2OSZ*

Video Digitizers

To get started transmitting on SSTV, you can use image files found on bulletin boards or prepared with a computer painting program. But to send live pictures of yourself, or objects inside or outside of your shack, you'll obviously need a TV camera (eg, a camcorder). You'll also require a *video digitizer* to get the video signal from the camera into your computer.* Many people mistakenly use the term *frame grabber* to describe all video digitizers. A frame grabber employs a lot of expensive, high-speed memory, an amount sufficient to hold *the entire image*, which it grabs in 1/30 second. Other video digitizers can be made at much lower cost by using less memory.

At the extremely low-cost end of the scale is one called Frugalvision. This clever little circuit uses only *six chips* and enough memory for *a single pixel!* It operates by grabbing *only one pixel per scan line.* During the first frame, it takes a pixel from the first column of each scan line. During the second frame, it snatches a pixel from the second column of each scan line, and so on. The trade-off is cost versus speed. For good results, you need a very stable video source—and the subject must remain *perfectly still* for *many seconds.* The amount of time depends on the number of columns, but it's about 8 seconds for 256 pixels and 21 seconds for 640 pixels.

Line grabbers are a reasonable compromise between these extremes. A line grabber has enough memory to hold a scan line. It grabs *all the pixels in the first scan line,* then transfers these to the computer. Then, it determines the next available line, grabs it, and transfers it to the computer. For example, a line grabber might take lines 1, 6, 11, 16, etc, from one frame, lines 2, 7, 12, 17, etc, from the next frame, and so on. The limiting factor is the *transfer time:* the time it takes to transfer the pixels from the line grabber memory to the computer. Total times are approximately 1/5 to 1/2 a second to capture the entire image, depending on the computer's speed. A stable video source and fairly stationary subject are required: But sitting still for a half second is a lot easier than remaining motionless for almost a half minute!

Here is a small sampling of typical, readily available video digitizers. All of them accept NTSC composite video. Some units also have S-video and RGB inputs; most have PAL versions available. This information was derived from the manufacturers' literature.—*WB2OSZ*

Product	*Resolution*	*Colors*	*Capture time (Seconds)*	*Price ($US)*
VIP-8800	(Not mentioned)	16 million	1/30	1995
CV-1010 + FG-1100	640 X 480	262,144	2	299 & 395
Computer Eyes/RT	512 X 512	16 million	1/30	599.95
Computer Eyes/Pro	640 X 480	16 million	24	399.95
DoubleTake AV+	640 X 480	16 million	1/2	345
VIP 640C	640 X 480	16 million	1/5	299.95
Frugalvision (kit)	256 X 244	64 gray scale	8	89.95 (kit)

Frugalvision is available from Idec, Inc, 1195 Doylestown Pike, Quakertown, PA 18951, tel 215-538-2600. The construction of this project is described in "Video Capture on the Cheap," *Radio Electronics,* Dec 1991, pp 37-46.

Computer Eyes/RT and Pro, Digital Vision, Inc, 270 Bridge St, Dedham, MA 02026, tel 617-329-5400, fax 617-329-6286.

CV-1010 NTSC-to-RGB converter, FG-1100 Video digitizer with 4 inputs, Imaging Automation Inc, 7 Henry Clay Dr, Merrimack, NH 03054, tel 603-598-3422, fax 603-598-3422.

DoubleTake AV+, Logos Systems Int'l, 100 Royal Oak Ct, Scotts Valley, CA 95066, tel 408-438-5012, fax 408-439-9440. (This unit also contains an *audio* digitizer.)

VIP 640C, Ventek Corporation, 31336 Via Colinas, Suite 102, Westlake Village, CA 91362-9897, tel 818-991-3868, fax 818-991-4097.

VIP-8800, IEV Corporation, 3030 S Main St, Salt Lake City, UT 84115, tel 801-466-9093 or 800-IEV-6161, fax 801-466-5921.

*By the time you read this, Pasokon TV should be able to take images directly from a VIP 640C digitizer. This means it won't be necessary to run a separate program to digitize images, save them to a file, then run Pasokon TV again and read the image files.

```
Set line number, L, to 1
Repeat:
  Wait for sync
  Wait for end of sync
  If it was vertical sync, set L = 1

  Gather 128 pixels
  Display pixels on line L
  Increment L
  If L > 120, set L = 1
```

Fig 7—Outline of typical software written to receive an SSTV picture.

counter is reset and the process starts all over again. The digital approach offers a few advantages over the analog filter approach. A single chip can contain the counter and handle several other functions as well. The analog approach requires a handful of op amps, resistors, capacitors, diodes and finally, an A/D converter. The digital approach has crystal-controlled accuracy—*and no adjustments are required.* The frequency-to-voltage transfer function of the analog version isn't exactly linear and can change with temperature, power-supply variations and component aging.

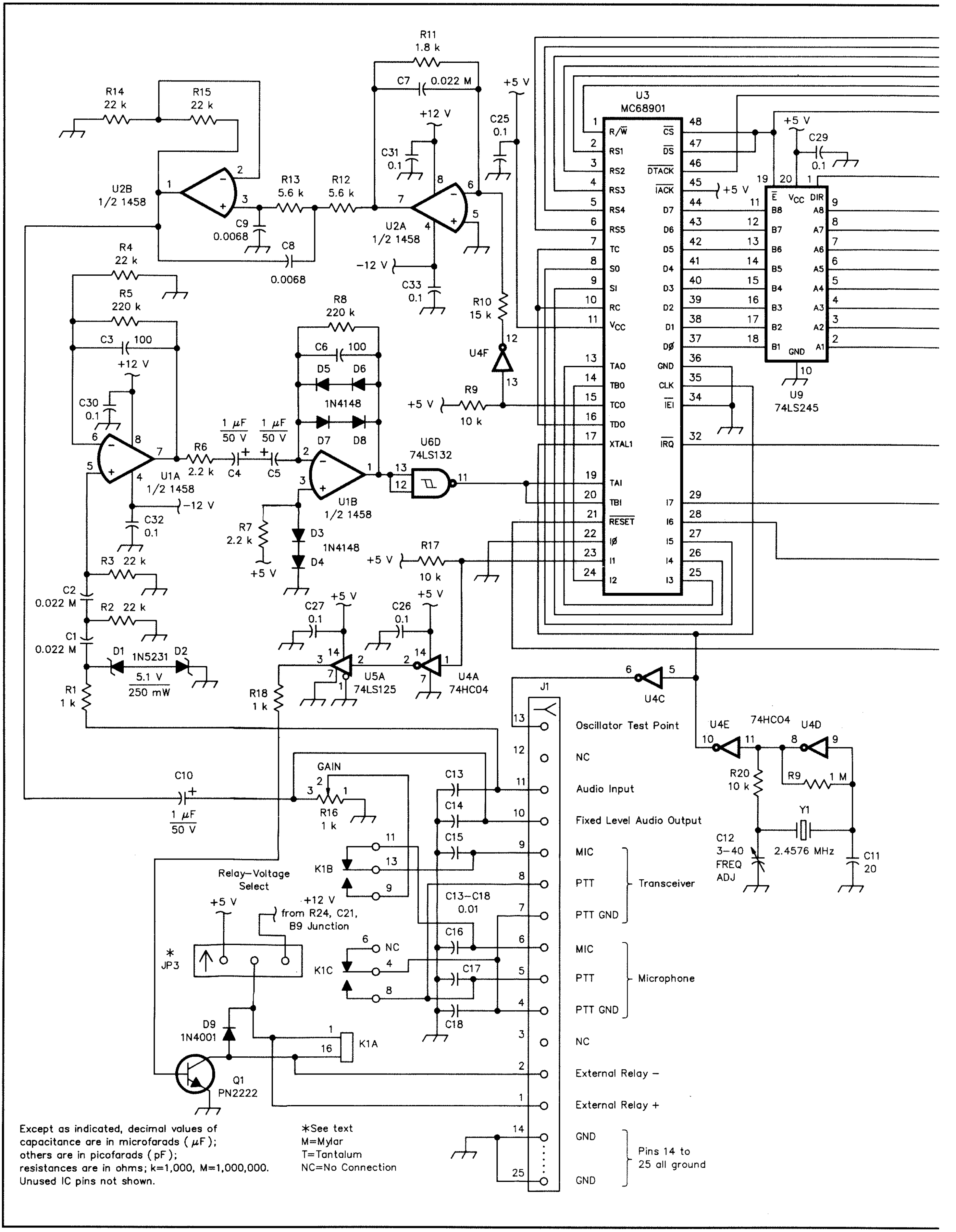
Digital signal processing (DSP) is another exciting possibility for making SSTV demodulators. With DSP, a high-speed A/D converter is used to sample the audio input: All filtering is done in *software.* This approach can be used to construct filters that are more flexible, accurate, stable and reproducible than their analog counterparts.

Once you have the tone-frequency information, the real work begins. Next, you must separate the composite signal into its synchronizing (sync) and video components. To reduce the effects of noise, the sync pulses are cleaned up by a low-pass filter and Schmitt trigger. Then, the sync is used to control the pixel sampling. Fig 7 contains a high-level outline of a program used to receive an 8-second B&W image. Receiving color isn't that much more difficult. For nonRobot modes, gather the red (R), green (G) and blue (B) scans for each line, combine them, and display a line in full color. Robot modes require considerably more calculation to undo the encoding.

Pasokon TV Interface

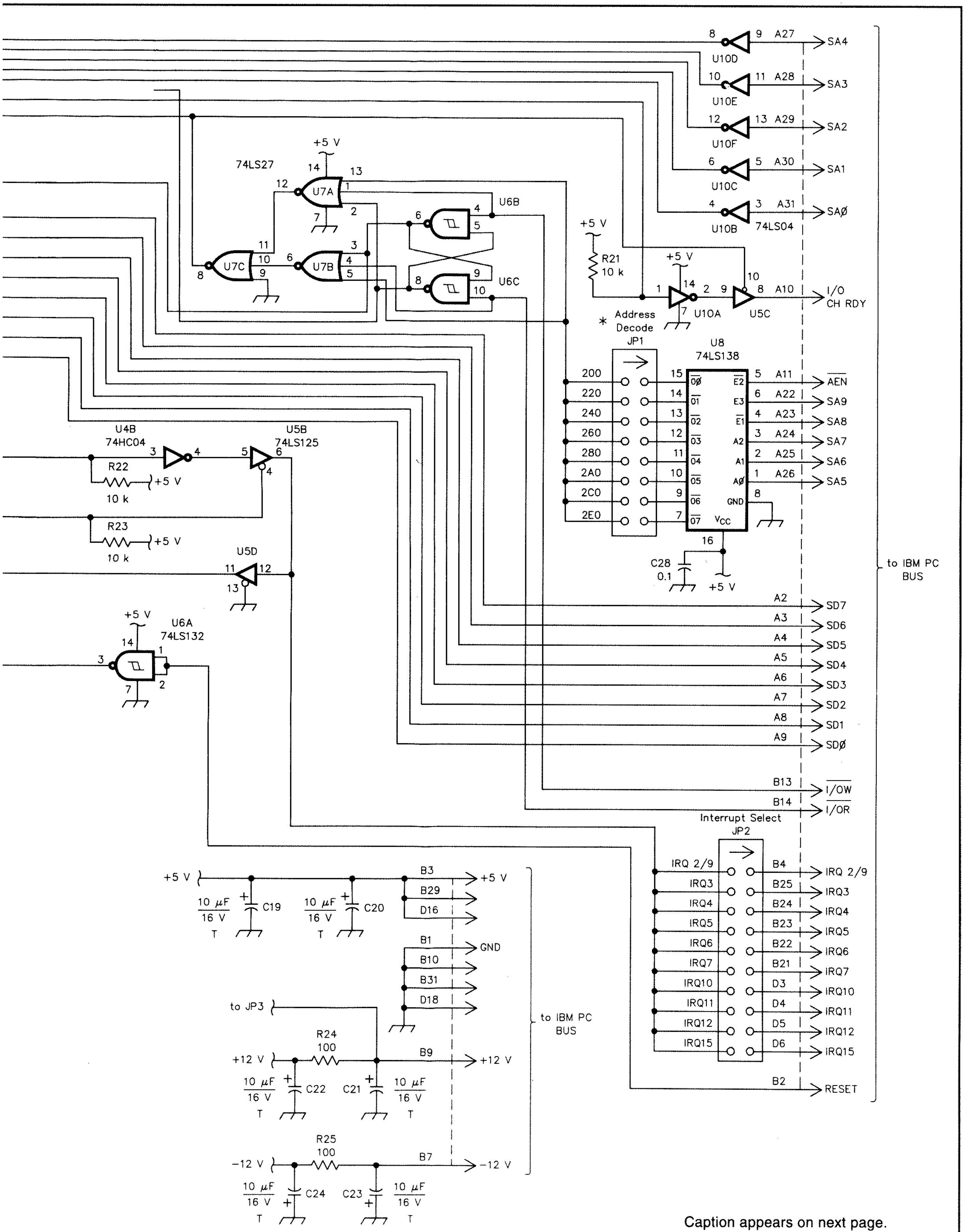
Fig 8 contains the Pasokon TV interface schematic. Received audio appears at pin 11 of J1. C1, R2, C2 and R3 act as a high-pass filter to remove low-frequency noise. U1A and its associated components form a low-pass filter that reduces high-frequency noise. Limiter U1B reduces the effect of signal-amplitude variations. Finally, a Schmitt trigger (part of U6) is used to shape the signal in preparation for the digital circuits.

U3 is a member of the Motorola 68000 microprocessor family. It contains four counter/timers, parallel I/O, a universal asynchronous receiver/transmitter (UART)



Except as indicated, decimal values of capacitance are in microfarads (μF); others are in picofarads (pF); resistances are in ohms; k=1,000, M=1,000,000. Unused IC pins not shown.

*See text
M=Mylar
T=Tantalum
NC=No Connection



Caption appears on next page.

Fig 8— (Figure appears on previous two pages.) Schematic of the Pasokon TV SSTV interface circuit. Unless otherwise specified, resistors are ¼-W, 5%-tolerance carbon-composition or film units. JP1, JP2 and JP3, are jumper positions; see text. (*QST* style ordinarily identifies jumpers as W numbers.)

C12—3- to 40-pF right-angle-mount trimmer capacitor.
D1, D2—1N5231 5.1-V, 250-mW, or 1N751 5.1-V, 250-mW Zener diode.
D3-D8—1N4148 silicon switching diode.
D9—1N4001 100-V, 1-A rectifier.
J1—DB25S right-angle PC-mount **D** connector.
JP1—8-position DIP male header (I/O address selection).
JP2—10-position DIP male header (IRQ selection).
JP3—3-position SIP male (relay voltage selection).
K1—5- or 12-V, DPDT, 16-pin DIP relay. (OMRON G5V-2 or Radio Shack #275-215.)
R16—1-kΩ, 15-turn, trimmer potentiometer.
U1, U2—1458 dual op amp.
U3—MC68901 multifunction peripheral.
U4—74HC04 CMOS hex inverter.
U5—74LS125 quad three-state buffer.
U6—74LS132 quad NAND Schmitt trigger.
U7—74LS27 triple 3-input NOR gate.
U8—74LS138 1-of-8 decoder.
U9—74LS245 octal transceiver.
U10—74LS04 hex inverter.
Y1—2.4576-MHz crystal.

Misc: PC board, rear-panel bracket with holes for a 25-pin **D** connector and access to C12 and R16 for adjustment; three shorting blocks for JP1, JP2, JP3; two 8-pin IC sockets (for U1 and U2); five 14-pin IC sockets (for U4, U5, U6, U7, U10); two 16-pin IC sockets (for U8, K1); one 20-pin IC socket (for U9); one 48-pin IC socket (for U3).

and an interrupt controller. Two of the counter/timers are used to measure the period of the incoming audio tone. Details of the timing are given in Fig 9. One counter measures the length of the positive half cycles. Another counter measures the negative half cycles. The samples are stored in variables Ta and Tb. Then, the audio frequency is computed as:

$$f = 1 \div (Ta + Tb) \qquad \text{(Eq 1)}$$

Another timer generates the tones used for transmission of the SSTV picture. A low-pass filter (U2) removes the high-frequency components before the signal is applied to the transmitter's microphone input. One of the parallel I/O bits is used to activate the relay (K1) that connects the transceiver's audio input to the SSTV tone generator and activates the PTT control. With a good old-fashioned electromechanical relay, you can always keep the interface connected between your microphone and transceiver. Less-expensive electronic switching isn't such a good idea here. With a chip instead of a relay, the SSTV interface must always be turned on, or you must swap cables to use the microphone.

The final counter/timer in U3 is the pixel-rate clock. If you're thinking about home-brewing your own SSTV system, be sure to use an *external* crystal-controlled timing source! With cache memories and interrupt handling occurring in the PC, any attempt to use software timing loops is doomed to failure. You should also resist the temptation to use the PC's programmable timer. This normally generates interrupts at about 18.2 Hz. Messing with this timing confuses the time-of-day clock, floppy-disk motor time-out, mouse double-click detection, screen savers and other time-dependent functions of the computer. The synchronous modes, such as AVT, require very accurate timing to avoid slanted pictures (see the sidebar, "*Slanted Pictures?*").

The rest of the schematic contains the interface to the computer's bus. Most of it's straightforward. U8 and jumper block JP1 are used to decode a group of 32 I/O addresses in the 2xx (hexadecimal) range. JP2 is used to pick an interrupt level not used by any other device in the system. The only "weird" part is the conglomeration of U6 and

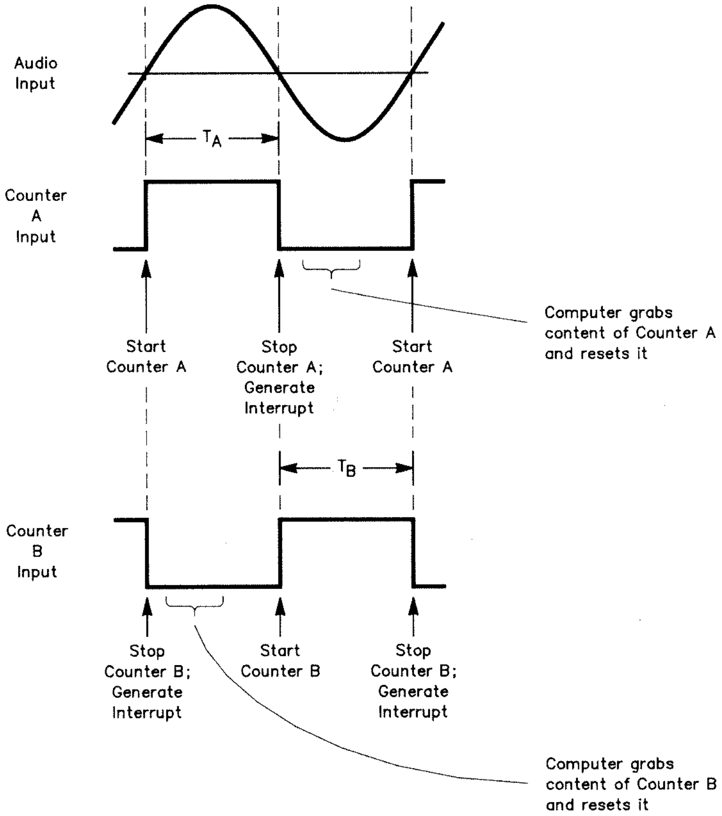


Fig 9—Details of input-period measurement.

Slanted Pictures?

As mentioned in the text, the synchronous modes, such as AVT, require very accurate timing to avoid slanted pictures. Let's quickly calculate the accuracy required.

One of the most popular SSTV modes is the AVT 94-second, which has 320 × 200 pixels using three color components per pixel. Multiply all that together and the result is 192,000 samples. (192,000 ÷ 2048 per second = about 94 seconds.) Suppose the maximum acceptable slant was an offset of 4 pixels at the bottom of the screen. This requires an accuracy of 4 ÷ 192,000 = 0.002% = 20 parts per million. Actually, if the transmitting station was off this much in one direction, and the receiving station was off the same amount in the opposite direction, the bottom of the picture would shift 8 pixels. Rather shabby, but it's the worst case. There's no need for a microcomputer time-of-day clock to have this accuracy, so many PCs probably won't even be this close. Be suspicious of *any* SSTV interface *that doesn't have its own crystal-controlled oscillator* that you can tweak to avoid slanted pictures!—*WB2OSZ*

U7 to process the I/O read and write signals. It might be more complicated than necessary, but it *absolutely guarantees* that the read/write control signal for U3 is stable slightly before, during and after the data strobe for reliable operation on a wide variety of systems.

Pasokon TV Operation

Fig 10 shows the screen layout for the software's main menu. It uses the 320- × 200-pixel, 256-color mode available on all VGA cards. The most frequent operations, such as mode selection, transmitting, receiving and full-screen image display, are activated by clicking a mouse button on a control-panel button on the screen. Less-common operations—such as reading files, generating test patterns, or zooming in on part of an image—are selected from pull-down menus. Some of them cause dialog boxes to appear for further interaction. Most features can also be accessed with keyboard equivalents, so a mouse isn't absolutely necessary to run the program.

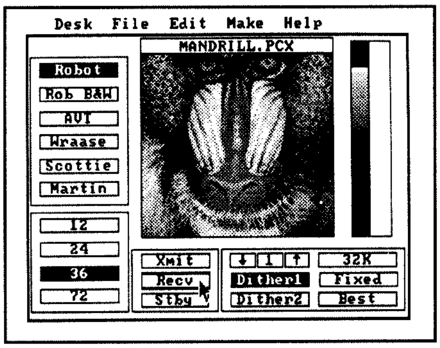


Fig 10—The Pasokon TV software main screen display. Although the software is mouse-oriented, keyboard commands can also be used to call up its various menus and help screens.

A Typical (?) SSTV Contact

Amanda Amateur fires up her Pasokon TV system and tunes to one of the SSTV calling frequencies: 3.845, 7.171, 14.230, 14.233, 21.340, 28.680 or 144.5 MHz. There, she hears Hambleton Ham calling CQ:

HH: "CQ CQ CQ. CQ Slow Scan. This is Kilowatt One Hotel Oscar Hotel."

AA: "K1HOH, this is Amanda, W7AA. Hello, Ham."

HH: "Hi, Amanda! Say, I just finished home-brewing a slow-scan TV system and need some help in testing it."

AA: "OK, let's see some pictures." Amanda uses a mouse to click on the **Recv** menu button, or presses **Enter** on the keyboard to begin receiving.

HH: "Here's a picture of my cat, Figaro, in Scottie S1." He sends the picture. (Note that *he announces the mode before transmission* because not all systems automatically select modes from the VIS code.) "How was that?"

AA: Amanda presses any key or mouse button to end receive mode. "That's a beautiful picture of a very talented animal!"

HH: "Talented? What do you mean talented?"

AA: "He's holding onto the ceiling! I'll send the picture back to you. Which mode would you like?" (Dear reader: The cat is actually *standing on the floor,* but Amanda's decided to play a joke on HH and send the picture *upside down* to HH. [It's certainly not a way to win friends with experimenters! HH better have a sense of humor, or AA is going to wind up in first position on HH's (expletive deleted) list!—*Ed.*])

HH: "How about Robot 72 second?"

AA: Amanda clicks on the **Robot** menu button and the color Robot transmission speeds appear below. She clicks on the **72** button. (Alternatively, she could have used the keyboard function keys.) Next, she picks **Invert** from the **Edit** menu to turn the picture upside down. There's no need to convert an image from one format to another—it's fully automatic.

"Here's your talented cat in Robot 72." (She clicks on the **Xmit** menu button, or presses the **X** key.)

HH: "H-m-m-m-m-m. The picture *is* upside down! Very interesting! How about sending me something in AVT 94?"

AA: With the mouse, Amanda selects **Open** from the **File** menu and gets a list of subdirectories and files. She clicks on the **DOGS** subdirectory and scrolls through the list until **BLACKLAB.GIF** is visible. After clicking on the file name and the **OK** button, the file selector disappears. Next, she selects **Rotate** from the **Edit** menu to rotate the image by 90 degrees and **Negative** to reverse the colors. "Here's a picture of my black Labrador Retriever in AVT 94." She clicks on **AVT, 94,** and **Xmit.**

HH: "The picture appears to be rotated by 90 degrees and the colors are all wrong. The dog is white and the grass is magenta! Dang! This seemed like such an easy program to write, but I've clearly made some serious mistakes! I'll have to go do some debugging. Thanks for your help, Amanda. 73! K1HOH."

AA: "Glad to help! I'll be here for a while. Give me a call when you're ready to try a new version. 73! W7AA clear and listening."—*WB2OSZ*

Although all images are stored as 320 × 240 pixels with 32,768 colors, the image portion of the main screen is only 160 × 120 pixels with 256 colors to be compatible with even the oldest and cheapest VGA card. The control-panel buttons in the lower-right screen corner select a full-screen image display. The **Fixed** button is the fastest, with a predetermined palette of 256 colors. The two **Dither** buttons produce the illusion of thousands of colors when you stand back 10 or 15 feet from the display. (Up close, it doesn't look so good.) The **Best** button calculates a custom palette of 256 colors for the particular image. This calculation can take a minute or more on a 33-MHz 80386 machine (math coprocessors aren't used by the software), so think before using the **Best** button on a slower machine. To get a feel for what an SSTV QSO might be like, see the sidebar "A Typical (?) SSTV Contact."

Many super VGA cards have a "HiColor" feature that allows the simultaneous display of 32,768 colors. The **32K** button selects this display mode to create beautiful pictures. If you're planning to buy a VGA card, consider one with the HiColor feature—they're not overly expensive.

Construction

Construction is fairly simple, especially with the available PC board (see Note 6). Wire wrapping the circuit takes a *lot* of patience because you have to make hundreds of connections. If you do use the wire-wrap approach, keep the interconnecting wires short (especially those connected to the PC bus!) and use plenty of bypass capacitors on the power-supply lines. Placing the variable capacitor (C12) and potentiometer (R16) near the rear edge of the board allows them to be adjusted from the back of the computer without removing its cover.

To help preserve the almost-lost art of home-brewing, I'll send a free copy of the software and additional documentation to anyone who sends me a photograph of their home-brewed Pasokon TV interface.

Adjustments

The Pasokon TV construction/instruction manual provides detailed information for the whole system. Fundamentally, you make two adjustments and install three SIP jumpers:

- Adjust C12 to put the 2.4576-MHz oscillator on frequency.
- Adjust R16 for the desired audio-output level.
- Install jumper JP1 to select the I/O address.
- Install jumper JP2 to select the desired IRQ level.
- Install jumper JP3 to select the relay operating voltage (5 or 12 V dc).

That's it.

Summary

After I gave several SSTV presentations and taking quick audience polls, a few trends became clear: (1) There is great interest in SSTV; (2) most people never get started because they think it must be very expensive; (3) most hams have an IBM PC-compatible computer. For them, using an SSTV interface with an IBM PC-compatible computer is the only *sensible* approach. (Table 3 contains additional information on how you can find out more about SSTV.)

I'm not the only one to come to these conclusions. Since the time this article was written, two other PC-based SSTV systems have become available; at least one more is rumored to be under development. There will probably be more new SSTV users in 1993 than any other year since it was invented!

Table 3

For More Information About SSTV . . .

Weekly nets:

Saturdays, 1500 and 1800 UTC
14.230 MHz

Magazines specializing in ATV:

The SPEC-COM Journal
PO Box 1002
Dubuque, IA 52004-1002
Tel 319-557-8791, fax 319-583-6462.
This journal features the column "Satellites, Facsimile & Slow-Scan TV Imaging" conducted by Fred Sharp, W8ASF.

*CQ-TV**
British Amateur Television Club
Dave Lawton, GØANO
Grenehurst, Pinewood Road
High Wycombe, Bucks HP12 4DD
England
Tel 0494 28899
This publication features a frequent column "SSTV Revisited" conducted by Roland Humphreys, G4UKL.

Amateur Television Quarterly
1545 Lee St
Suite 73
Des Plaines, IL 60018
Tel 319-266-7040

Old A5 Magazine *reprints:*
ESF Copy Service
4011 Clearview Dr
Cedar Falls, IA 50613
Tel 319-266-7040

Amateur Television Today!
QCD Publications
PO Box 1677
Weatherford, TX 76086
Tel 817-599-7509

Handbooks:
SLOW SCAN TELEVISION HANDBOOK
Don Miller, W9NTP, and Ralph Taggart, WB8DQT
2nd ed (Peterborough, NH: 73 Inc.)
2nd printing March 1975; 1st ed printed Dec 1972.

*Subscriptions to *CQ TV* can be arranged through Wyman Research or *ATV Quarterly* so US subscribers don't have to deal with foreign currency exchanges.

Notes

[1] Robot Research was the dominant supplier of SSTV equipment for many years, first with the Robot 400, then the 400C and finally, the 1200C, which arrived around 1985.

[2] AVT Master available from AEA. See ad in any ham magazine.

[3] SSTV (kit #168) available from A & A Engineering, 2521 W LaPalma, Unit K, Anaheim, CA 92801, tel 714-952-2114, fax 714-952-3280. Charge cards accepted.

[4] J. Langner, "SSTV—The AVT System Secrets Revealed," *CQ-TV 149,* Feb 1990, pp 79-80.

[5] M. Emmerson, "SSTV Compatibility! Robot 1200C and Wraase SC-1," *Spec-Com Journal,* p 39, no date.

[6] Complete kits are available for $199.95 from: John Langner, WB2OSZ, 115 Stedman St #Q, Chelmsford, MA 01824-1823, tel: 508-256-6907. Kits include a *four-layer* PC board (with plated through-holes and gold-plated edge-connector, solder mask and silk-screen), all board-mounted components, software and printed documentation. Kits *do not* include the connectors required for attaching the interface to a transceiver because the connectors used differ among transceiver manufacturers. For assembled and tested units, add $30. Specify your preference of 5.25-inch (1.2-Mbyte) or 3.5-inch (1.44-MB) diskette. Free shipping in the USA; foreign orders add $15 for shipping and handling. Massachusetts residents must add 5% sales tax.

To use the Pasokon TV system, you need an IBM PC AT or compatible computer operating under PC/MS-DOS with a 80286 (or faster) CPU, a minimum of 640 kbytes of RAM and a VGA display. A mouse is strongly recommended, but not required.

Because this is a *four-layer* PC-board, the ARRL *does not* offer a PC-board layout or part-overlay template.

[7] C. MacDonald, "A Narrow-Band Image Transmission System—*Part I,*" *QST,* Aug 1958, pp 11-15, 140, and 142; —*Part II,* Sep 1958, pp 31-36, 146 and 148;

[8] Section 9 of Robot model 1200C color scan converter instruction book. Also in ESF reprint booklet, number 110, p 43.

Bibliography

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B. Brown, ATV, *73 Amateur Radio Today,* Aug 1992, pp 50-53. (This column contains a discussion of several video digitizers.)

D. Goodman, "SSTV with the Robot 1200C Scan Converter and the Martin Emmerson EPROM Version 4.0," *73 Amateur Radio Today,* Jul 1991, pp 46-48.

J. Langner, "SSTV—The AVT System Secrets Revealed," *CQ-TV 149,* Feb 1990, pp 79-80.

J. Langner, "Color SSTV for the Atari ST—Part I," *73 Amateur Radio,* Dec 1989, pp 38-42; Part II, Jan 1990, pp 41-43.

G. Cameroni and G. Morellato, "get on SSTV—with the C64," *ham radio magazine,* Oct 1986, pp 43-47, 51 (translated by Jim Grubbs, K9EI).

R. Taggart, "The Romscanner," *QST,* Mar 1986, pp 21-27. [Editor's note: By the time this article appears in print, V 2.0 of the Romscanner will be available. Circuit changes obsolete the older schematic. PC boards and a new schematic copy are available from FAR Circuits, 18N640 Field Ct, Dundee, IL 60118-9269; price not available at press time. A PC-board template and part-overlay drawing are available free from ARRL HQ. Please send a business-size SASE and address your request for the TAGGART ROMSCANNER V 2.0 PC-BOARD TEMPLATE to: Technical Department Secretary, ARRL, 225 Main St, Newington, CT 06111.

C. Abrams, "In Search of the Perfect Picture," *QST,* Dec 1985, pp 14-17.

M. Schick, "Color SSTV and the Atari Computer," *QST,* Aug 1985, pp 13-16.

C. Abrams and R. Taggart, "Color Computer SSTV: Part I," *73 Magazine,* Nov 1984, pp 10-13, 16, 18, 20 and 21; Part II, Dec 1984, pp 18-22, 24-26 and 28-32.

John Langner, WB2OSZ, obtained his ham license around 1970 at the Tech Hams ARC (thanks, Don, WA2NRE!). John has a BS in computer science from the Rochester (NY) Institute of Technology. John is an incurable home-brewer and has had a number of construction articles published in BYTE, 73 Magazine, ham radio *and* QST.

For the last several years, John has dedicated himself to making low-cost SSTV available for everyone. When not busy tinkering with ham radio gadgets, spending time with his wife and three sons (and getting some occasional sleep!), he's a Member of the Technical Staff at Advanced Visual Systems, Inc, a leading supplier of scientific visualization software.

Phil Calciano, KA1KZB, provided all the SSTV pictures appearing in this article. (other photos by Kirk Kleinschmidt, NTØZ.)