By Ralph E. Taggart, WB8DQT

Digital Slow-Scan Television

A new communications option, digital SSTV takes only a computer and the transceiver that's already in your shack.

Slow-scan television (SSTV) has been around for about 45 years now and there's been significant evolution and development of the mode. Early in its history all of the equipment was big and bulky and you had to build it yourself. There was essentially just a single SSTV mode—120 line, low-resolution, gray scale images. These were transmitted during an 8 second interval and fleetingly displayed using a long-persistence P7 phosphor of a surplus radar display CRT. A view of the imaging equipment of an early station can be seen in Figure 1.

Today, almost all SSTV operations are carried out using home computers equipped with sound cards. There are a large number of mode options including medium or high-resolution gray scale and color images. All of these options make SSTV one of the most versatile options for image communications on all bands from HF through microwaves. Medium resolution (320 by 240/256 × 24 bit) color modes are the most popular and typically require slightly less than two minutes for transmission or reception. Given reasonable HF conditions, the results can be excellent (Figure 2A).

With all the changes that have occurred in slow-scan, it is still an analog image transmission system—subject to the effect of marginal signal paths, interference, noise, fading or multipath (Figure 2B). Given the seemingly miraculous performance of digital communications modes such as PSK, many assume that digital image transmission should result in a significant performance improvement compared to conventional (analog) SSTV. In the last few years, just such a digital imaging system has been developed and it can now be encountered frequently on the HF bands. Digital Slow Scan Television (DSSTV) makes available a new set of imaging options in Amateur Radio, but the mode tends to complement rather than replace the capabilities of conventional SSTV. To understand both the strengths and limitations of this new imaging mode, we need to take a closer look at what DSSTV is and how it can be used.

DSSTV Basics

DSSTV is the result of the creative effort of Barry Sanderson, KB9VAK, and the enthusiastic work of a number of experimentally inclined amateurs who helped turn it into a practical image transmission system. An explanation of how the mode works is illustrated by a look at a simpler, non-imaging mode—phase shift keying. The most common form of PSK is BPSK (biphase shift keying) that modulates an audio subcarrier back and forth between two possible phase states. DSSTV uses the same basic principle with two critical differences:

- The signal format phase modulates a total of eight subcarriers (ranging from 590 to 2200 Hz at 230 Hz intervals).
- Instead of just two possible phase states, each subcarrier has nine possible modulation states.

The actual modulation format involves two levels of Reed-Solomon coding with enough redundancy to support robust error correction. A complete description of the coding strategy is beyond the scope of this article but is thoroughly documented in KB9VAK's presentation at the 2000 Dayton Hamvention (**www.svs.net/wyman/examples/HDSSTV/**). While most commonly used for image transmission, the signal format can handle any digital file. Throughput varies somewhat with file size, but averages approximately 92 bytes/second. This transmission rate is critical in defining the imaging capabilities of the system and we will return to it shortly.

What's In a Name?

The KB9VAK modulation/signal format is most properly known as *RDFT* (redundant digital file transfer). This transmission format can handle a wide range of data transmission, in addition to images. If the format is used to encode and transmit image files (the essence of DSSTV), the mode meets all current requirements for use on our HF bands. If it is used to transmit other data formats, however, the mode exceeds

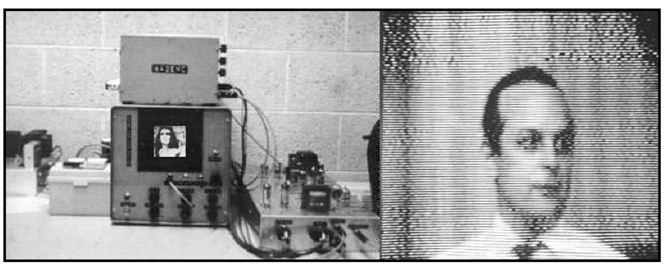

Figure 1—If you wanted to get on slow-scan in the pioneering days, you had to build a lot of specialized (and large) tube-type equipment. Shown on the left is equipment built by the author and in use at W8SH, the Michigan State University Amateur Radio Club in 1968. The pictures were all 128 line, gray scale images, which were "painted," line-by-line, on the face of surplus radar display tubes equipped with long-persistence P7 phosphors. This image from SMØBUO, received at W8SH in 1968, required 8 seconds for transmission and display.

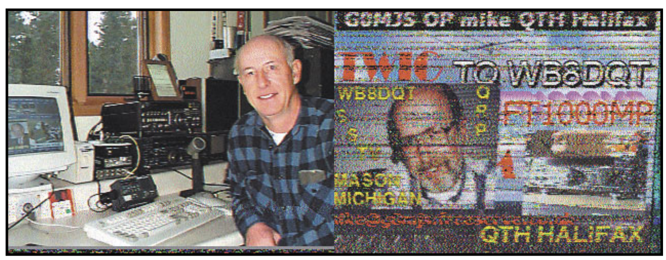

Figure 2—When band conditions are good and interference levels are low, conventional slow-scan can deliver images of high quality (left), illustrated by this picture from WØLMD in Colorado, as received by the author in Michigan. In contrast, a marginal signal path, fading, multipath, noise or interference can all degrade the quality of the received signal (right), as evident in this image from GØMJS received by the author.

the current 300 baud limit imposed by the FCC for our frequencies below 28 MHz (see the accompanying sidebar, "Is the Transmission of Digital Image Files Permissible Under Part 97 Rules?").

Software

Transmission and reception of an image or any other file involves three distinct phases:

1. The original data file (typically an image) is processed and used to generate an audio WAV file. This will be the form of the transmitted file. The WAV file includes tuning and start data, a data header, the main body of the file, and a trailer. The time required to produce the WAV file depends on the original file size and the speed of the computer. For most practical image files the coding time can range from a second or two for a fast computer (2 GHz or faster) to a minute or more for a slow system (400 MHz).

2. The WAV file is routed through the transmitter. At the receiving station, the incoming WAV file is temporarily recorded to the computer hard drive. Data transfer occurs at approximately 92 bytes/second. The transmission and recording time is a simple function of the original file size.

3. The receiving computer then processes the recorded WAV file to reconstruct the original source file. This step is data intensive and the processing time depends on the size of the file, how much error correction has to be performed and the speed of the computer. This step can take 15 minutes or more on a relatively slow computer while a 2 GHz machine can complete the job in 15 seconds.

KB9VAK developed a series of *DOS* program modules to perform these and other functions associated with DSSTV transmission and reception. Initially these modules were used in sequence or linked via batch files to perform essential functions. More recently, two shell or "front-end" *Windows*-based programs have been developed that still use the *DOS* modules but which provide a *Windows* user interface and which more or less automate the processing sequence for DSSTV transmission and reception. Both programs are freeware and may be distributed to other Amateurs.

DIGISSTV by Erik Sundstrup, VK4AES, is designed for *Windows XP*, although some features will function under other versions of *Windows*. The program, along with KB9VAK's *DOS* routines, can be downloaded at **www. kiva.net/~djones/digisstv**.

Roland Zurmely, PY4ZBZ, wrote *DIGTRX*. This program is widely used because it is completely functional under any version of *Windows*. It can be downloaded from **www.kiva.net/~djones/digtrx.htm**. Since all of my computers are running *Windows 98*, the examples illustrated will be based on *DIGTRX*.

There is no complicated installation; you simply have to be sure that both the shell software and *DOS* executable files are located in the same directory. Hardware interfacing is identical to any other sound card based software including conventional SSTV. If you have a homebrew or commercial interface that you have been using on other modes, it will do just fine for DSSTV.

Configuration consists of selecting the serial (COM) port to control the TR function. If you are already operating other

Is the Transmission of Digital Image Files Permissible Under Part 97 Rules?

The idea of sending computer digital image files has prompted some discussion as to whether this is permitted in Part 97 of the FCC rules. Here's the picture.

Q Is HF transmission of digital images classified as *Data*, and thus subject to the provision in §97.307(f)(3) that "The symbol rate must not exceed 300 bauds..."

A No. It is classed as *Image* communications with permissible emissions defined in §97.3(c)(3). The *Data* symbol rate limitations in §97.307(f)(3) through (8) do not apply to this mode. §97.309 (RTTY and data emission codes) does not apply to image transmissions. However, these transmissions need to abide by §97.307(f)(2), that: "No non-phone emission shall exceed the bandwidth of a communications quality phone emission of the same emission type."

Q But, slow-scan television and facsimile that amateurs have been transmitting over many years use raster scanning. Digital graphic formats are different. Doesn't that make them *Data*?

A Actually some graphic file formats use raster scanning, albeit with some compression to eliminate redundancy. Not everything that is "digital" is automatically "*Data*." For example, digital voice is not *Data*, as elaborated in the sidebar to the article "Practical HF Digital Voice," by Charles Brain, G4GUO, and Andy Talbot, G4JNT, which appeared in the May/June 2000 issue of *QEX*. That sidebar was prompted by some of the same questions.

Q What are the emission designators for digital image transmission?

A 97.3(c)(3) defines them as follows: "Facsimile and television emissions having designators with A, C, D, F, G, H, J, or R as the first symbol; 1, 2 or 3 as the second symbol; C or F as the third symbol; and emissions having B as the first symbol; 7, 8 or 9 as the second symbol; W as the third symbol." Nevertheless, HF amateurs image transmission systems are most likely going to consist of an audio baseband signal modulating a single-sideband suppressed-carrier transmitter (the letter J as the first symbol), tone modulated (2 as second symbol) and C or F as the third symbol. If you assume a bandwidth of 2.8 kHz, the complete emission designation is 2K80J2C or 2K80J2F, depending on whether it is considered facsimile (C) or television (F).

Q How do I tell whether to classify it as facsimile or television?

A For the most part, it's not necessary to do that because Part 97 calls them both *Image*. For the purist, however, you have to start from the mindset of the day when the terms facsimile and television were coined. Both were raster scanned. Facsimile was considered a *telegraphy* system of sending a printed or handwritten page (a fixed graphic image) to be printed at the receiving end. Television was a picture (moving, transient or sometimes stationary) from a camera or similar device meant to be displayed on a cathode ray tube (CRT). Well, since the advent of personal computers, much of that has changed. It is possible to generate an image using a camera, a scanner or even a computer program. Similarly, the image at the receiving end can be displayed on a CRT, a liquid crystal display (LCD) screen or projector, printed on paper or even just stored in computer memory available for display at the option of the operator. So, the definitions of facsimile and television are getting a little blurred and the FCC's use of the word *Image* encompasses both without having to make a distinction.

Q What image formats are permissible as digital image transmissions?

A Certainly JPEG or GIF are the main ones that come to mind. However, there are numerous others and they continue to evolve.

Q Where in the band should this type of transmission be operated?

A The considerate operator would probably choose the same segments where conventional SSTV has been operating.

Q Does the transmission have to be purely image?

A *Image* and *Phone* emissions are permitted in the same segments of HF bands. There is no problem transmitting images and voice alternatively or simultaneously. Note that §97.307(f)(2) says "The total bandwidth of an independent sideband emission (having B as the first symbol), or a multiplexed image and phone emission, shall not exceed that of a communications quality A3E emission." *—Paul Rinaldo, W4RI, ARRL Technical Relations Manager*

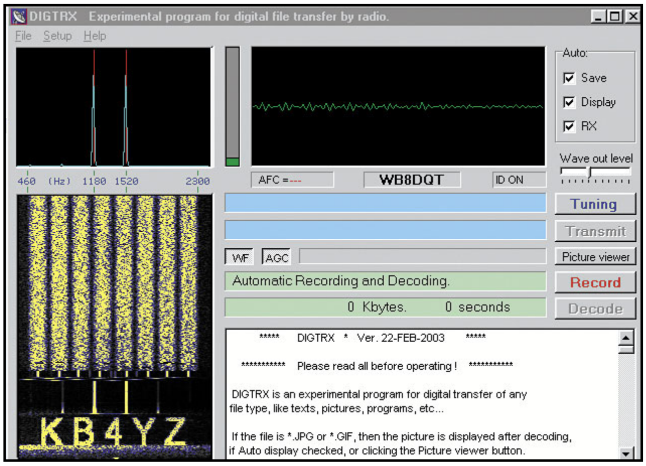

Figure 3—The *DIGSSTV* operating screen. Three different displays provide a detailed look at signals as they are received. The window at the upper right and center functions as a basic oscilloscope display. Two spectrographic displays share a common frequency calibration. The smaller window at the upper left shows a real-time spectrogram of the received signal while the elongated waterfall display below it permits you to watch the signal over time.

digital modes, use the same port values for DSSTV. You will also have to set the input level to the soundcard. With the software AGC disabled, adjust the soundcard input level so that subcarrier peaks on the upper-left spectrograph hit about 1/3 maximum amplitude with a clean signal. At that point you can re-enable the software AGC. The soundcard output level (or your interface LEVEL control) should be carefully adjusted so not to overdrive the audio input of your transceiver.

If you are already operating on PSK, use your current PSK power level. With a typical 100 W transceiver, your peak output power should probably not exceed 20-25 W. Under no circumstances should you switch in any audio processing. If you overdrive the audio, the resulting intermodulation (IMD) products will result in an excessively wide signal and it will be impossible for anyone to decode your transmissions. Fine adjustments to the audio drive level can be made using the WAVE OUT LEVEL slider on the upper right of the *DIGTRX* panel.

Operational Considerations

Finding Activity

On 20 meters there appears to be a reasonable amount of DSSTV activity on 14.233 and 14.240 MHz, especially on weekends. There is an excellent noontime net (US Eastern time) run by KB4YZ on or near 7.173 MHz—stations will often be exchanging pictures until late afternoon.

Getting on Frequency

You must be tuned to the other station with an accuracy of a few Hz if you are going to be able to reliably decode file transmissions. Make sure your RIT is off and ask the other station to send you "tuning tones." When you see the two-tone signal displayed in the spectroscope display on the upper left, as shown in Figure 3, tune the transceiver so the audio peaks align with the red calibration lines at 1180 and 1520 Hz and you are on frequency. If you are asked to send tuning tones, the TUNING button on the right side of the menu will cause the tuning tone sequence to be sent automatically.

Receiving a File

Although the various receiving functions can be initiated manually, it is much easier to let the software do the work. In the case of *DIGTRX*, you can automate the complete receiving sequence by clicking the RX (auto-start, stop, and decode), DISPLAY (automatically displays the image if it is a GIF or JPEG file), and SAVE (auto-saves the image in the AUTOSAVE subdirectory of your working directory) boxes in the AUTO area in the upper right side of the screen (Figure 3).

The spectral waterfall display in Figure 3 shows the basic sequence of events at the start of an image file transmission:

- If the transmitting station has enabled the call sign option, the subcarrier frequency will be swept to "paint" the station's call sign across the waterfall display. If the call sign option has not been enabled, the name of the software will be displayed.
- The software will send the two-tone tune signal. If you haven't already optimized your tuning, this is your last chance to do so.
- The receive software will start to record the incoming WAV file while displaying the eight phase-modulated subcarriers on the waterfall. They will also be displayed in the window above the waterfall. Unlike standard slow scan, there is no progressive display of the incoming image. DSSTV is not a real-time imaging mode and SSTV is probably not an ideal descriptive name. Unlike conventional SSTV, you cannot get an image after the file transmission has started. The transmission of this particular file (Figure 3) from KB4YZ was very clean. Amplitude of the eight subcarriers was essentially equal, indicating a flat pass-band for both the transmitter and receiver. Selective fading and multipath, which normally appear as patterns of darker patches migrating across the subcarrier waterfall display were absent, as was any interference. Total transmission time is proportional to the file size and will usually be announced by the transmitting station prior to transmission.
- When the file is complete, the software will automatically stop the WAV file recording and begin the process of decoding the file. The decoding time required is a function of the size of the original file, how much error correction had to be attempted, and the speed of your computer. A 400 MHz machine is slow for this application and decoding even modest images will take many minutes. In contrast, a 2 GHz system can finish the same job in 15-30 seconds. Unlike conventional SSTV, the decoding is an all-or-nothing process. You will either get a perfect copy of the image or you will get nothing at all.
- If the decoding was unsuccessful, a message will be posted describing the problem. Some of these messages are more helpful than others. If the decoding was successful, the statistics for the various image blocks will be posted. If the file was a GIF or JPG image file, the picture will be displayed. For other image formats, you will have to use other viewing software and retrieve the file from the AUTOSAVE subdirectory. While the all-or-nothing aspect of DSSTV may be depressing if you did not get a file for some reason, any other stations on frequency that got the image can, in effect, relay you a perfect copy.

Time and Resolution Constraints

In preparing image files for transmission via DSSTV, a great deal of attention has to be paid to both time and resolution.

Time

How much time can we spend transmitting an image on the amateur bands? The absolute answer is 10 minutes, given the station identification requirements imposed by the FCC. The real-world limit is considerably shorter. Extensive experience with analog SSTV has shown that on busy HF bands (20 meters and lower in frequency), something around two minutes is the practical limit. Higher frequency bands can be used for higher resolution images, where transmission times can exceed six or seven minutes, as long as the frequency isn't particularly busy. In practice, 120 seconds is a fair time limit for DSSTV images as well. While the higher frequency bands could be used for longer transmissions, increasing the transmission time simply raises the probability that something will occur that will generate a decoding error and cause the loss of the entire image. This is in contrast to transmitting

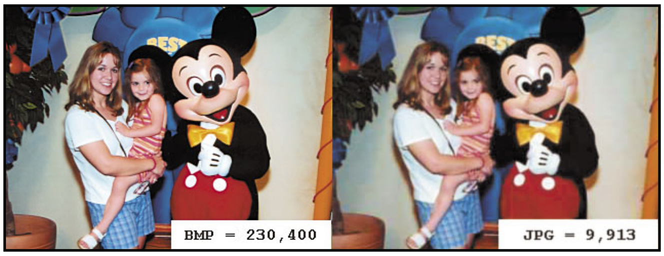

Figure 4—With the bandwidth and time constraints of Amateur image transmission on HF, significant compression of the image files is the only approach for the transmission of pictures of any size and complexity. The picture on the left is a 320×240 24 bit color image of the type that would typically be encountered when operating analog SSTV. This file, in uncompressed BMP format has a file size of 231,478 bytes. On the right, the same image has been subject to significant JPEG compression, dropping the file size down to 11,814 bytes for DSSTV transmission (see text). Although casual examination would suggest the two versions of the image are identical, Figure 5 shows that this is far from being the case.

Figure 5—The central areas of these images have been magnified to the point where the pixel structure of the images is clearly evident. The sample of the BMP image on the left shows pixel structure but there are no obvious artifacts and the image tones are smooth and continuous. On the right, the severely compressed JPG image shows artifacts with respect to spatial and color sampling errors.

high-resolution images using analog SSTV where a momentary problem during transmission may result in errors with little practical impact on image quality.

Image File Size

If we set the maximum transmission time at around 120 seconds and we know that DSSTV data is transmitted at approximately 92 bytes/second, our maximum practical file size would be in the order of 120×92 or 10-11k. Smaller is better in terms of required transmission times and you could certainly stretch the 10k limit a bit, but 10k is a good reference point to look at our really big problem—image resolution. Image resolution involves both spatial resolution (the amount of detail in the image) and tonal resolution—the fidelity of the grayscale or color-coding of the individual pixels. The subject is discussed in detail in *The ARRL Image Communications Handbook*,[1] but we will simplify things by just looking at 320×240 medium-resolution images that dominate in the world of conventional SSTV. Such a picture has 320×240 or 76,800 pixels.

How large a file is required for the raw image data depends on the type of image we wish to send. Binary (black and white) images (typically line drawings), can encode 8 pixels per byte of file storage and thus produce the smallest image files. Gray scale images are typically encoded using one byte/pixel (256 gray scale values), so file size is essentially equal to the number of pixels in the image array. In contrast, 24 bit color images require 3 bytes of file storage for every image pixel and thus generate the largest image files for any particular image resolution. Thus, for the three primary image types— black and white, gray-scale and color—a 320×240 image can be characterized with respect to both file size and transmission time (see Table 1).

Table 1
Image Transmission Time

Image Type	*Raw File Size*	*Transmission Time sec(min)*
Binary	9,600 bytes	104(1.7)
Gray scale	76,800 bytes	835(13.9)
24 bit color	230,400 bytes	2504(41.7)

It is obvious that only the binary (line drawing) raw file falls under the arbitrary 10k, 2 minute "limit." In contrast, transmitting photographic images, either gray scale or color, is impractical given the extended time required to transmit the raw file data. The way around the file size/transmission time bottleneck is *image compression*. Approaches to image compression fall into two broad categories: lossless as opposed to lossy compression algorithms. Lossless compression formats (such as GIF) result in no penalty with respect to image resolution but the degree of compression that can be achieved is limited. The more complex or detailed the image, the lower the compression value that can be achieved.

Other approaches to compression such as JPEG can achieve much greater compression ratios but do so at the expense of some loss of image data. Unfortunately, to get the degree of compression we need (a factor of 20 or more in the case of the color image), we are going to have to accept some loss to squeeze the file size to approximately 10k.

JPEG compression techniques, widely used for Internet images, can really perform miracles when it comes to reducing image file size. Figure 4 (left) shows a 320×240×24 bit color image, typical of those transmitted via analog SSTV. Unfortunately, with a file size of over 230k this is not a file you can readily send via DSSTV. Using some pretty severe JPEG compression, the image file size was compressed to just over 11k and the image file can be sent in just 128 seconds (Figure 4, right). Unfortunately, the two versions of the image are not the same. Figure 5 shows the central area of the BMP (uncompressed) and the JPG (compressed) images from Figure 4. The differences are quite striking. While the uncompressed image is resolution limited (basically a medium-resolution image by analog SSTV standards), the color tones are continuous and smooth. In contrast, the JPEG image shows artifacts, spatial and tonal, resulting from the file compression. While DSSTV can transmit such an image file without error, the effective resolution of the image is quite modest compared to the original source picture.

Perfect transmission of an image that is notably corrupted by compression artifacts is a mixed blessing. Such compression artifacts are very common in DSSTV image samples on the Internet (see the directories of DSSTV images at **www.kiva.net/~djones/**) and illustrate the problem of applying excessive compression in an attempt to reduce transmission time. DSSTV is definitely not "high definition" SSTV, especially with reference to gray scale or color images. To make the most of the significant capabilities provided by DSSTV, image size, type, resolution and compression must be juggled to optimize the quality of the images that are sent. Figure 6 shows a sample of typical over-the-air images from 40 meters and illustrates the tradeoffs. Binary and line art images (Figure 6A) can be relatively large because such images already enjoy an effective 8:1 compression by virtue of the fact that the

[1]Available from your local dealer or the ARRL Bookstore. Order no. 8616. Telephone toll-free in the US 888-277-5289, or 860-594-0355, fax 860-594-0303; **www.arrl.org/shop/**; **pubsales@arrl.org**.

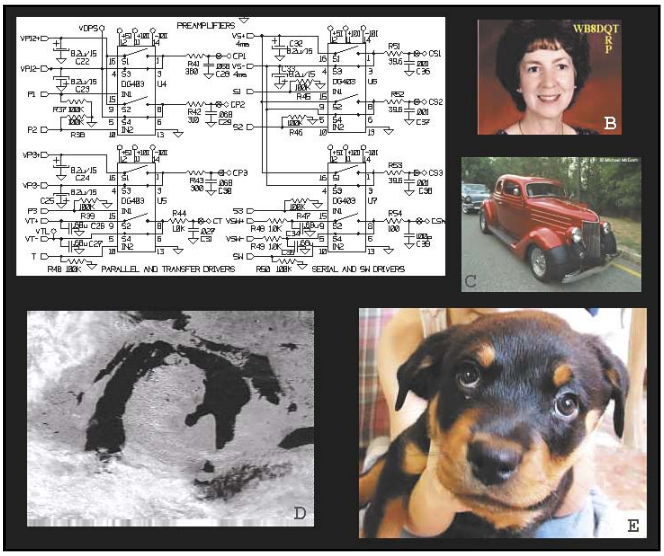

Figure 6—DSSTV images have no fixed format, unlike conventional slow-scan. Within the limits discussed in the text, there is a wide range of spatial and tonal resolution options. In general, the largest practical images are true black and white (binary) images such as the schematic (from KB4YZ) shown top left. Relatively small color images (under 200×200 resolution) can usually be compressed to the point where image transmission requires approximately one minute for transmission (B and C). B is an image file transmitted by the author at QRP power levels (approximately 2 W average output) and retransmitted by W9PKC. The image of the car (C) is the first DSSTV image I was able to receive and was transmitted by W9VMT. Because gray scale coding only requires 8 bits/pixel, compared with 24 bits/pixel for high quality color, gray-scale images of 320×240, such as the weather satellite image (D) can be compressed for transmission in about 1.5 minutes. This image was transmitted at QRP power levels by the author and retransmitted by K3DCC. Color images—320×240, 24 bit (E, transmitted by KB4YZ) present a challenge, as relatively high levels of compression are required to achieve practical HF transmission times (2 to 3 minutes).

pictures only have two color/tonal values—black or white. Drawings of the type shown here typically have large areas of white and lossless compression techniques, such as GIF, can often reduce file size to an acceptable value. If you wanted to send schematics and other printed material, DSSTV would be an excellent medium that can produce error-free file transfers.

Gray scale images (Figure 6D) enjoy an inherent 3:1 file size advantage compared with 24 bit color images and thus will require less compression to meet a specific file size limit. In general, you can transmit a larger or more detailed image if you can use gray scale as an alternative to 24 bit color. The same principle applies to color images if the image itself can be reduced with respect to color content. For example, if you can convert a 24 bit scan of a color cartoon to 8 bit color (256 color values), as in the case of gray scale images, you can use less compression to hit your target file size.

You will occasionally see large test patterns that have been transmitted in on-the-air-tests in as little as 30-40 seconds. This kind of promotion of DSSTV is highly misleading. The test patterns, by virtue of the image structure and number of actual colors, can be very highly compressed without introducing many image artifacts. Such test images have almost nothing in common with the photographic images (gray scale or color) that represent the mainstay of analog SSTV activity.

Detailed, full-color (24 bit) images present the greatest challenge. The most judicious approach is to do some reduction in image size and resolution in order to employ less compression. For this reason, you will encounter many images that are significantly smaller than our initial 320×240 example (Figure 6B and 6C) and thus don't require quite as much compression. While this may seem like rolling the technological clock back to earlier image formats with less resolution, the images can be quite effective because they can be reconstructed without error at the receiving end of the circuit. Figure 6E shows an excellent example of a 320×240 color image that was sent by KB4YZ in just a bit over two minutes.

The quality that Dave achieved with this image is a function of two factors: the limited color range of the picture and the use of advanced compression formats (such as JPEG 2000), which can achieve a specific degree of compression with fewer artifacts. If you need to transmit more complex images, you can always break a large image down into smaller subsets that can be transmitted individually. If the image subsets are received at all, they will be perfect, which means you can patch the pieces together to reconstruct the larger picture.

The Bottom Line

With the advent of *Windows* shell programs such as *DIGISSTV* and *DIGTRX*, DSSTV has reached a point where it can be part of the SSTV mainstream. DSSTV introduces a new toolbox of capabilities with respect to image communications, and every active SSTV operator should get some experience using the mode. It is unlikely that DSSTV, in its present form, will replace analog SSTV. Analog SSTV operates in real time and when conditions are good, images, while not error-free, can have a higher effective resolution than pictures that are practical using DSSTV. When conditions are poor, even a severely degraded image can be adequate to confirm a new state or country (see Figure 2B). While DSSTV operation is not yet as spontaneous as conventional SSTV, perfect image file transfers are possible, even under adverse conditions using low power.

DSSTV is an excellent mode for the operator who wants to try QRP on slow-scan, but it is demanding in terms of careful tuning, drive adjustment and hardware stability. You will also appreciate the virtues of a faster computer, especially while you are waiting to see if you did succeed in capturing that last image. Passing images around in the context of a net or other group is easy and, unlike analog SSTV relays, will not introduce additional image degradation.

DSSTV is certainly not a high-definition mode and it is quite unlike SSTV in that images are not displayed in real time. It is fun, highly effective and worth a look by both experienced and novice SSTV operators. Not all SSTV operations demand or even need perfection, but where it is desirable or useful, DSSTV will deliver. Whether it is analog SSTV or DSSTV, we have certainly come a very long way since slow-scan was introduced almost 45 years ago.

All photos by the author.

Ralph E. Taggart, WB8DQT, first licensed in the 1950s as WA2EMC, has been involved in amateur image communications since the early 1960s. He has authored several books and articles on the subject, among them The ARRL Image Communications Handbook. *He enjoys operating low power PSK31, CW, SSTV and ATV. Dr Taggart is currently a Professor in the Department of Plant Biology, the Department of Geological Sciences and Curator of Fossil Plants at Michigan State University. He and his wife Alison have three daughters and two granddaughters. You can contact him at 602 S Jefferson, Mason, MI 48854 or* **taggart@msu.edu**.