4

Formats of slow-scan TV transmission

4.1 Black and white SSTV systems

The earlier modes of SSTV transmission were displayed on long persistent monitors with radar CRT. The duration of transmission for each image frame took 7.2 to 8 seconds, and when the last line was received the first line was still visible. It was possible to see the whole picture in a darkened room.

Both 7.2s and 8s modes were used in the same period. The 7.2 s frame speed mode, was used in Europe while the 8 s were used in America. The synchronization of signals is derived from the electrical mains – 50 or 60 Hz. If an image was synchronized at 60 Hz and received on 50 Hz equipment, it was still readable, but the image was a little distorted. For long-distance QSOs, it was possible to change the oscillator to achieve European or American synchronization.

The disadvantages of 8s SSTV are low image resolution and a loss of synchronization due to signal interference. The loss of synchronization could lead to the loss of a few lines or the whole image.

The differences between modern SSTV modes and this old system are many, but one parameter remains the same. Almost all new systems use 1200 Hz frequency for sync pulses and the frequency band from 1500 Hz (black) to 2300 Hz (white) for video signals. Also, the old 8s mode is still supported by many SSTV programs for transmission. It is important to note that the 8s mode has the shortest transfer time and should be used in special conditions.

4.1.1 Modes for digital converters

There are many modes for B&W image transmission which differ in transfer time and resolution. Wrase and Robot modes are implemented in modern converters;

the transfer is extended to 256 lines and the transmission time is also prolonged to achieve better horizontal resolution.

Historically common modes are the 16-second mode with 128 lines, the 32-second mode with 256 lines and the 64-second mode with 256 lines; which provides maximal image quality. All these modes are related to the original 8s mode and also have an image aspect ratio of 1:1. The number of lines, columns or both were simply multiplied twice. This design was used in Wraase's B&W converters.

While Wraase's modes were derived from the European 7.2s mode, Robot Research developed an original system for their converters. Robot's modes aren't simply derived by "doubling" parameters but are derived from line speed. While the American 60 Hz/8s standard has a transfer speed of 900.0 lpm, Robot's line speeds for new modes were set at 600.0 lpm so that 120 lines were transferred in 12s and 240 lines in 24s. The mode with the best resolution has a line speed of 400,0 lpm and a total transmission time of 36 seconds.

The Robot SSTV system reserves the first 16 or 8 lines (for a 240 or 120 line image) for gradation grayscale. The scale can be used to tune the signal more precisely.

Although Robot Research cooperated with Copthorne MacDonald, they ignored the trend in amateur construction of digital converters with doubled modes. Nevertheless, the Robot converter *Robot 300* became quite popular despite the high price tag of over $800 in the mid-seventies.

During the '70s and '80s, the ham radio market was not the only outlet for SSTV converters, but companies found opportunities in the telecommunication market and sold SSTV monitors and cameras as devices for image transmission over telephone lines.

4.1.2 BW transmission with computer software

An example of B&W mode implemented with computers is the AVT 125 BW mode of the *Amiga Video Transceiver* system and it is suitable for good quality image transfer in circa 2 minutes. The mode has a vertical resolution of 200 lines because the Amiga computer resolution was 320×200. The AVT system is different from the previous B&W modes because it has no line sync like WEFAX. The transmission is based on a fully synchronous communication and the exact timing of corresponding stations. This special feature is described in more detail in **chapter 4.2.5** about color AVT modes.

There is also the FAX480 mode for the high-resolution transmission, with 512×480 image resolution described further in **chapter 4.3.1**.

Early B&W modes Wraase and Robot, need to be synchronized with both line and vertical synchronization. The line speed describes the free-run speed, but in reality, it can be deviated up to ± 5 %.

Mode	Resolution	Aspect ratio	Sync. (ms)	Scan line (ms)	Line speed (lpm)
7.2s (50 Hz)	120×120	1:1	5.0	55.0	1000.0
8s (60 Hz)	120×120	1:1	5.0	60.0	900.0
Wraase SC-1 8	128×128	1:1	5.0	55.0	1000.0
Wraase SC-1 16	256×128	1:1	5.0	115.0	500.0
Wraase SC-1 16 Q	128×256	1:1	5.0	55.0	1000.0
Wraase SC-1 32	256×256	1:1	5.0	115.0	500.0
64 s mode	256×256	1:1	5.0	115.0	250.0
Robot B&W 8	160×120	4:3	10.0	56.0	900.0
Robot B&W 12	160×120	4:3	7.0	93.0	600.0
Robot B&W 24	320×240	4:3	12.0	93.0	600.0
Robot B&W 36	320×240	4:3	12.0	138.0	400.0
AVT 125	320×400	4:3	—	312.5	192.000
FAX 480	512×480	1:1	5.12	262.144	224.497
SP-17 BW	128×256	4:3	5.0	62.0	895.520

Table 4.1: Parameters of black and white SSTV modes.

Modern modes like FAX480 and AVT 125 BW need accurate precision of line speed, because just a little deviation of values in tenths causes image slant and distortion.

The advantage of longer transmission is improved image quality. The disadvantage is that a lot of time is needed for the transfer, which could be better utilized for the transmission of color images.

4.2 Color SSTV modes

You might find it incredible that the first color transfer was made before the era of digital converters using long persistence monitors. Each color image channel was obtained using color filters, which were subsequently held in front of the camera. A sample result could be that the first channel transferred was blue, then green and the last red. Slightly more difficult was the processing on the receiver side. This was because each color channel had to be photographed from the monitor screen and then the resultant color picture was combined from all three components. It was a very laborious process, but it was put into practice a few times!

Robot B&W 8

Robot B&W 12

Robot B&W 24

Robot B&W 36

Figure 4.1: Comparison of Robot system's BW modes.

Further experiments with color SSTV transmission were based on frame sequential transfer. Three complete images were transferred in 8s mode and each contained one color channel, together they formed one color image. During the broadcast, a color original was progressively scanned with a BW camera through each of the color filters. Received images had to be stored in a digital converter in three different memories. When simultaneously displayed on a color monitor they created a full-color image. This is the reason why BW modes of Robot and Wraase families have three different VIS codes for BW transfer. The codes are sent for adjustment of color components for frame-sequential transmission. Individual images were usually sent in the order of red – green – blue. But the order of the channels could be changed under the agreement of corresponding stations, or some images could be broadcast repeatedly. With such a method, it is possible to transfer only static scenes. If an object moves during manual scanning of an image, the color components do not correspond and the resulting image has colored ghosts.

The transfer was not always reliable; due to interference and fade-outs, the image component had to be sent several times. And in practice, it was sometimes problematic to complete all color channels. To improve color transmission the *line* *sequential* transfer was developed. The principle is that it transmits a single image and each scan-line carries all three color components. Receiving equipment can already display color images during transmission. This method where the color image is transferred in one frame is referred to as *SFC – Single Frame color*.

More properties of SSTV systems will be introduced in following sections, with all their pros and cons and details of mode formats described in detail.

4.2.1 Wraase SC-1

This line sequential system was first among newly developed SFC systems. Wraase SC-1 comes from the workshop of famous SSTV engineer Volker Wraase, DL2RZ. The system was most likely created by modifying existing equipment to operate in 8s mode or for frame-sequential transmission.

Each scan-line begins with 6.0ms sync, then a green component follows and then the blue and red components. Separate sync of 6.0 ms length precedes each color component.

Wraase SC-1 has a major deficiency. If the receiver loses sync during interference, then the display system loses the ability to synchronize colors. Because all lines are sent in the same way, the color components cannot be recognized and the probability that the system reverts to correct color sync is equal to one-third. In practice, the system works, but when the noise level is too high, the received image contains few color bands as the converter loses and restores synchronization. For this reason, an additional sync pulse was added to subsequent productions of the SC-1 converter. It consists of a truncated 5ms sync before the red line, which is immediately followed by a short pulse of 2300 Hz frequency lasting 1-2 ms. It allows the converter to regain synchronization after the noise subsides. Additional synchronization occurs as a thin red stripe in the left edge of the image.

All SC-1 modes have an image aspect ratio of 1 : 1. The original SC-1 mode is the 24s mode with 128 lines, so the image quality is not better than the 8s mode, but the colors improve the picture.

The system was soon upgraded for modes with the longer transmission. First, the number of lines was doubled to 256 and the transfer extended to 48 seconds. The last SC-1 96s mode has a better horizontal resolution for good image quality.

The professional converter Wraase Electronics SC-1 was most popular in Germany, but its market share was lower in comparison to the Robot converters produced in the same period.

4.2.2 Robot color system

The *Robot* modes are named according to the converters in which they were implemented. They are scan-converters Robot 400C, 450C and 1200C. They were produced in San Diego by Robot Research Inc.

Mode name	Transfer time	Resolution	Color sequence	Scan line (ms)				Speed (lpm)
				Sync	G	B	R	
Wraase SC-1 24 Color	24 s	128×128	G–B–R	6.0	54.0	54.0	54.0	333.3
Wraase SC-1 48Q Color	48 s	256×128	G–B–R	6.0	108.0	108.0	108.0	175.4
Wraase SC-1 48 Color	48 s	128×256	G–B–R	6.0	54.0	54.0	54.0	333.3
Wraase SC-1 96 Color	96 s	256×256	G–B–R	6.0	108.0	108.0	108.0	175.4

Table 4.2: The Wraase SC-1 scan-line timing.

They do not use RGB color coding as SC-1, but YCrCb. Scan-lines consist of a luminance signal Y followed by differential chrominance signals $R - Y$ and $B - Y$. Due to this, the color modes are compatible with their B&W variants. So a 12s color mode can be displayed by 8s monitors, etc.

From a total of 8 modes, 4 are intended for color transmission. Half of the color modes use YCrCb in a 4:2:0 format. The scan-line contains only one chrominance signal, and colors are obtained from the average of two adjacent lines in the original image. The other two modes use the 4:2:2 format and send all color information in one scan-line.

The original Robot system uses asynchronous transfer. To receive the image, it is needed to detect the vertical sync (VIS code). And for proper reception of the image, the sync pulse must be detected. This process is a major disadvantage.

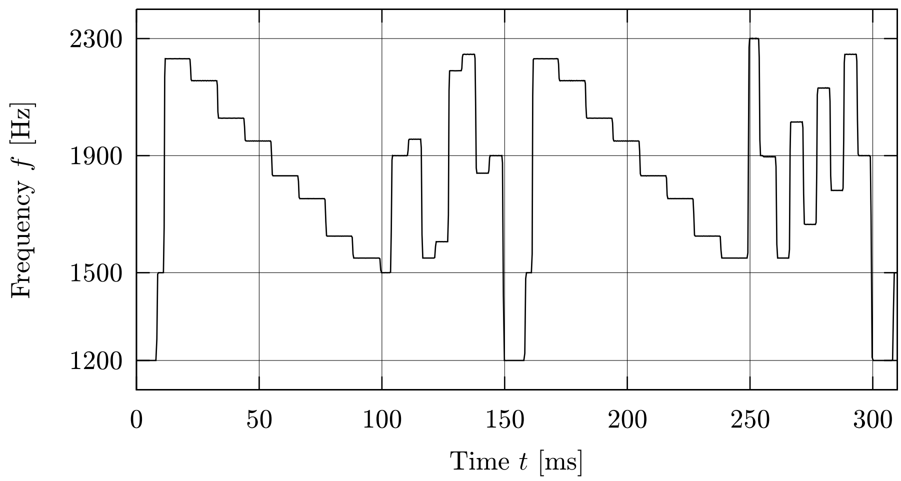


Figure 4.2: Two scan-lines of Robot 36 Color when color bars are sent.

The scan-line is composed of the starting sync, followed by a short 3.0ms gap of 1500 Hz and then the image part with luminance and chrominance. The chrominance differential signals begin with additional sync pulses. The 1500Hz sync is before

$R - Y$ and the second 2300Hz is before $B - Y$. Due to the additional sync with a different sync frequency, it is possible to re-synchronize 4 : 2 : 0 formats after an interruption. The chrominance syncs are separated from the scan-line with 1500Hz gap that lasts 1.5 ms.

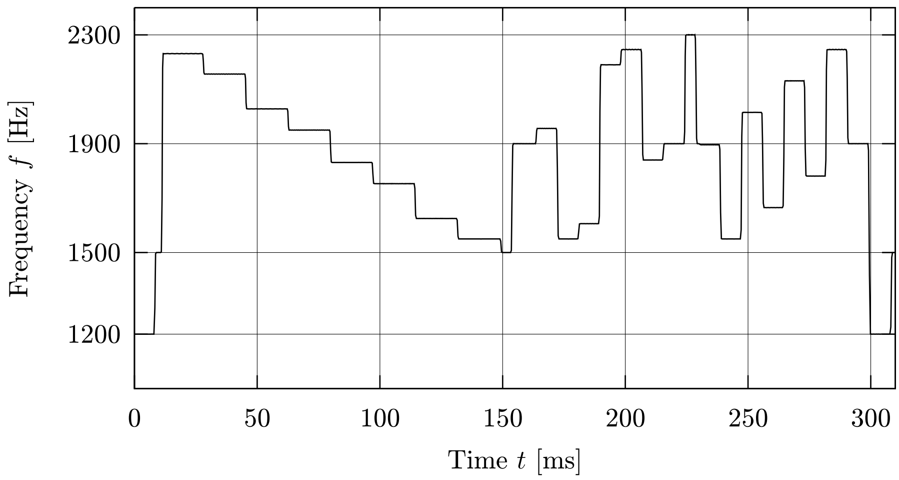


Figure 4.3: The scan-line of Robot 72 Color when the color bars are sent.

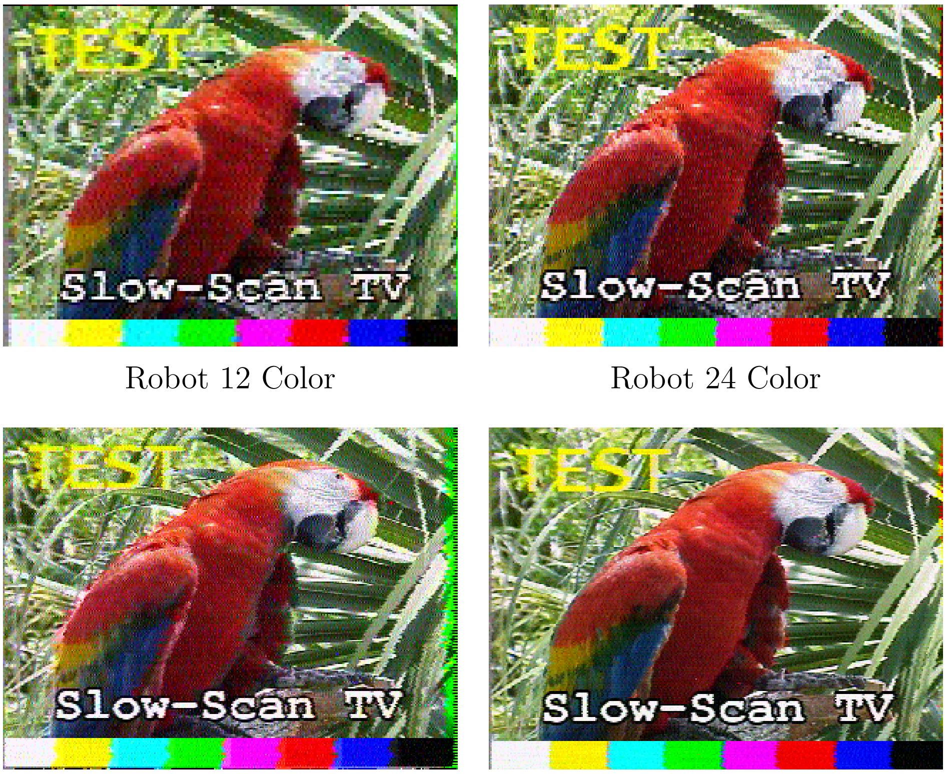
The main disadvantage of the Robot modes lies in color-coding because the receiver must be perfectly tuned to the SSTV signal. Otherwise, the image hue is distorted when the deviation is greater than ±50 Hz. For this reason, Robot Research introduced the transmission of a gray gradation scale at the beginning of image transfer and the receiver device can auto-tune for a video signal.

The whole frame has 256 or 128 lines, of which the first 16 or 8 lines are reserved just for gradation scale. Some converters and PC software add some basic station info, such as call sign, and this part of the frame is called "header".

The memory storage capacity of the Robot 1200C converter allows it to store an image with a resolution 256×240 pixels or four images with 128×120, and they are displayed in a 4 : 3 aspect ratio.

The fastest mode of the Robot family and the fastest color SSTV mode is the 12s mode. It contains 120 lines transmitted in the 4:2:0 format. Another mode is 24s with a 256×120 resolution and 4:2:2 color format. The other two modes allow the transfer of images in 256×240 resolution, either in less quality for 36 seconds in a 4:2:0 format or in better quality in 4 : 2 : 2 format for 72 seconds.

Although the Robot modes were pushed away by modern synchronous modes that are more resistant to interference, the 24s and 36s modes are faster than modes with RGB color coding and have better resolution than RGB modes with the same transmission time. You can find their benefits on VHF with FM transmission because it eliminates the need for precise tuning.



Robot 12 Color | Robot 24 Color

Robot 36 Color | Robot 72 Color

Figure 4.4: Comparison of Robot color modes.

Robot 36 Color was used in MAREX[1], SAREX[2] and ARISS[3] programs for SSTV transmission from orbital stations Mir, ISS and space shuttle missions. It is a pretty good compromise between image quality and transfer time, because space stations on low earth orbit can be received within just 10 minutes during their orbit.

4.2.3 The Martin synchronous system

The creator of this popular system is Martin Emmerson, G3OQD. He originally named it “New Modes”, but to avoid confusion between other newly emerging SSTV modes, the community universally named modes after their creators. The Martin was created to overcome SFC problems in systems like SC-1 due to two main changes.

The first change was that instead of three separate syncs before each color component, there is just single sync sent before each scan-line. The horizontal sync lasts 4.862 ms. After the horizontal sync, the green component is sent, then blue

[1] Mir Amateur Radio Experiment
[2] Shuttle Amateur Radio Experiment
[3] Amateur Radio on the International Space Station

Mode name	Transfer time	Resolution	Color format	Compatible B&W mode
Robot 12 Color	12 s	160×120	4 : 2 :0	Robot B&W 8
Robot 24 Color	24 s	320×120	4 : 2 :2	Robot B&W 12
Robot 36 Color	36 s	320×240	4 : 2 :0	Robot B&W 24
Robot 72 Color	72 s	320×240	4 : 2 :2	Robot B&W 36

Mode	Color	Sync pulses of			Scan-line			Speed
name	sequence	line	color	color	Y	R—Y	B—Y	(lpm)
Robot 12 Color	YCrCb	7.0	3.0	—	60	30		600.0
Robot 24 Color	YCrCb	12.0	6.0	6.0	88	44	44	300.0
Robot 36 Color	YCrCb	10.5	4.5	—	90	45		400.0
Robot 72 Color	YCrCb	12.0	6.0	6.0	138	69	69	200.0

Table 4.3: The Robot parameters and scan-line timing.

and last is the red component. Between each color component, there are short gaps of 1500 Hz lasting 0.572 ms. Just like in the SC-1, the sequence green – blue – red was chosen. Regardless of the order in which components are sent, the image quality will not change. But it is important that the receiving device identifies which component is being currently received.

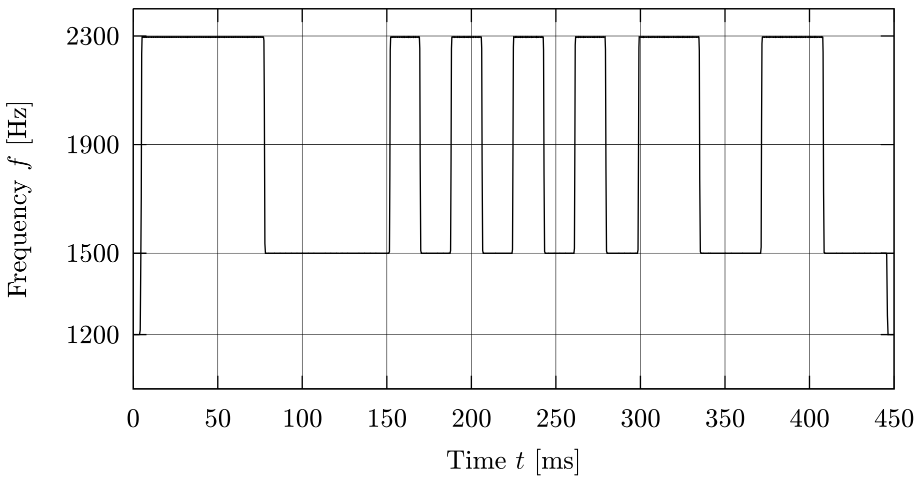


Figure 4.5: Scan-line of Martin M1 when color bars are sent.

An important feature of using only one sync before beginning the color scan-line sequence is that a converter will not replace the individual color components and degrade the color information. In time intervals where the line sync is not transmitted, the gaps are filled with a reference level of black at 1500 Hz for 0.572 ms.

The second improvement has a substantial effect on image reception. Unlike the Robot or SC-1, the detection of horizontal syncs is not necessary during the reception. And the broadcast between stations is fully synchronized. The results of the use of such a system are sharper images and more contrasted edges. Although the transmission conditions on the lower HF bands often do not allow the transfer of the image in 100% quality, old systems relying on line sync usually lose synchronization in such conditions.

The Martin system was originally implemented as a modification of the Robot 1200C converter and it preserves the transmission of the header gradation scale.

Robot 36s Color   Martin M1

Figure 4.6: A comparison of systems in real conditions on the 3.7MHz band.

Line syncs and inner scan-line gaps have a similar duration at all four speeds, but the number of lines and horizontal resolution for each mode is different. Although the syncs aren't necessary for transmission, they are still transmitted at the beginning of each scan-line in order to synchronize the converter at any time during the reception. It is important because it consumes a lot of broadcast time and the station does not have to wait for the start of a new frame, but a receiver can get synchronization at any time during transmission.

The Martin system allows us to work with four different modes/speeds. The most popular version is the Martin M1 with 256 lines per frame in two minutes. Other modes of the Martin system have either half the line or half the horizontal resolution of the best quality M1. The mode M4 has the lowest quality and 128 lines. Modes Martin M1 and M2 are often used between European stations.

Mode name	Transfer time	Resolution	Color sequence	Scan line (ms)				Speed (lpm)
				Sync	G	B	R	
Martin M1	114 s	320×256	G–B–R	4.862	146.432	146.432	146.432	134.3947532
Martin M2	58 s	160×256	G–B–R	4.862	73.216	73.216	73.216	264.5525975
Martin M3	57 s	320×128	G–B–R	4.862	146.432	146.432	146.432	134.3947532
Martin M4	29 s	160×128	G–B–R	4.862	73.216	73.216	73.216	264.5525975

Table 4.4: The Martin scan-line timing.

4.2.4 Scottie

These modes were created by Eddie T. J. Murphy, GM3SBC. He modified the original firmware of Wraase SC-1. Martin Emmerson also implemented Scottie modes to Robot 1200C later on.

Scottie has the same improvements as the Martin system does, but its scan-line composition and scan timing are different.

After vertical synchronization, the sequence of scan-lines is; a 1.5ms short gap of 1500 Hz, then a green component, a 1.5ms short gap again, a blue component, then horizontal sync, another gap and lastly, a red component. This unusual order is the result of the system adaptation to SC-1, where the additional sync was used right before the red component. Syncs are permanently sent for any time synchronization during the reception.

The Scottie relies on exact timing like the Martin, although the original version for SC-1 was not fully synchronous and syncs were still processed by the converter. But in newer systems the modes are implemented for free-run reception, so the system is equivalent to the Martin.

The implementation of Scottie in Robot 1200C slightly differs because the first scan-line includes an additional 9.0ms sync at the beginning of the scan-line right after vertical synchronization. All other modes implemented in Robot 1200C have sync at the beginning of the scan-line but the Scottie has the sync in the middle of the scan-line which then caused color distortion. Perhaps some other implementation of Scottie has this difference too.

The Scottie system also has four conventional modes (and a special one described later). Two with 256 lines per frame and two with 128 lines. The difference in timing is not the same as in the Martin, where the line speed of the faster mode is exactly twice the speed of the slower mode, so the speed of the faster mode is lower than twice that of the slower mode.

Image quality in the Scottie and Martin modes is the same. Theoretically, slightly better quality can be achieved in Martin M1 than in Scottie S1 due to longer transmission, but the difference is imperceptible.

The Scottie S1 and S2 are quite popular for North American stations and can often be heard on high-frequency bands.

4.2.4.1 Scottie DX – special mode for long-distance transfers

This mode of the Scottie family achieves the best possible results in the transmission of slow-scan television images. There is one simple reason for this; the transmission takes about 2.5 times longer than Scottie S1.

There is an extended duration of the scan-line, but the duration of sync and gaps between color components remained the same. This improvement is best seen on the receiving side. The longer transmission time supports better image quality.

The improvement relies on the fact that; each pixel can be read more times during signal sampling and that the loss of a few samples does not affect the overall quality. It means that each pixel takes a long time and this gives better noise and phase distortion immunity. But these qualities are compensated by a very long image transmission time of about 4.5 minutes. During this time, two images with the same resolution can be sent with other RGB modes.

The Scottie DX mode offers high-quality images, but sometimes the optimal conditions for DX connections do not last long enough for the transfer of a whole picture.

Mode name	Transfer time	Resolution	Color sequence	Scan line (ms)				Speed (lpm)
				Sync	G	B	R	
Scottie S1	110 s	320×256	G–B–R	9.0	138.240	138.240	138.240	140.1148942
Scottie S2	71 s	160×256	G–B–R	9.0	88.064	88.064	88.064	216.0667214
Scottie S3	55 s	320×128	G–B–R	9.0	138.240	138.240	138.240	140.1148942
Scottie S4	36 s	160×128	G–B–R	9.0	88.064	88.064	88.064	216.0667214
Scottie DX	269 s	320×256	G–B–R	9.0	345.600	345.600	345.600	57.12653528

Table 4.5: The Scottie scan-line timing.

4.2.5 Amiga Video Transceiver

AVT modes were originally intended for SSTV operations with Amiga computers. AVT author Ben B. Williams, AA7AS developed a dedicated interface and software which was produced by AEA (Advanced Electronic Applications Inc.). Although the creator claimed that this system was a revolution in SSTV transmission, these modes did not gain popularity like other modes. The AVT modes are practically not in use today.

A reason for this could be the fact that the manufacturer wanted to keep the image scan parameters of the system, secret. However, by intercepting signals and reverse engineering, the parameters of the AVT modes were implemented in other devices by the SSTV community. This was done without the additional software tools that made the AVT unique.

The AVT system contains four of line sequential RGB modes and one B&W. The scan-lines have no gaps between color components and a really unusual thing is that; the modes do not use any horizontal sync. Another unusual feature is the mandatory function of vertical synchronization, that is sent as a digital header before the image transfer begins.

The AVT family contains 5 modes and each of them has the following four options:

1. Default variant is the same as conventional SSTV modes, but does not have any line syncs.
2. *Narrowband variant* uses a shorter band for video signals from 1700 Hz for black to 2100 Hz for white.
3. *QRM variant*, that uses picture interlacing just like in analog television.
4. The combination of the QRM and narrowband variant.

The fastest mode is the AVT 24 with 120 lines and it is transferred for 31 seconds. The next mode is AVT 90 with a resolution of 256×240 and an image quality slightly worse than in the Martin M1. ATV 90 sends each color component in 125.0 ms, thus the speed is 2048 pixels per second (in binary notation this gives a nice rounded number). The other two modes have somewhat atypical resolutions in comparison with other SSTV modes, but these resolutions are normal system resolutions on Amiga computers. It is AVT 94 with 320×200 and AVT 188 with the same line speed, but twice the scan-lines – 320×400. The image is displayed in an aspect ratio of 4 : 3 in both cases.

For some SSTV systems/scan-converters, the detection of vertical sync is a must. So, the VIS code is repeated three times for accurate reception. VIS is necessary for image reception when *no* line sync is sent and later synchronization is not possible. The original AVT software does not need to receive VIS but relies more on the digital header.

After a series of VIS code, there is a digital header (see **fig. 4.7**), which contains synchronization data. It is a sequence of 32 frames of 16 bits. Each frame contains only 8 bits of information, but it is sent twice – first in normal form and second inverted. Normal and inverted parts can be compared for error detection. Each frame starts with a 1900Hz pulse while data modulation uses 1600 Hz for the representation of logical zeros and 2200 Hz for logical ones. Narrow-band variants use 1700 Hz for zeros and 2100 Hz for ones. Both variants use a modulation speed of exactly $2048/20 = 102.4$ Bd, so the data pulse has a length of 9.766 ms.

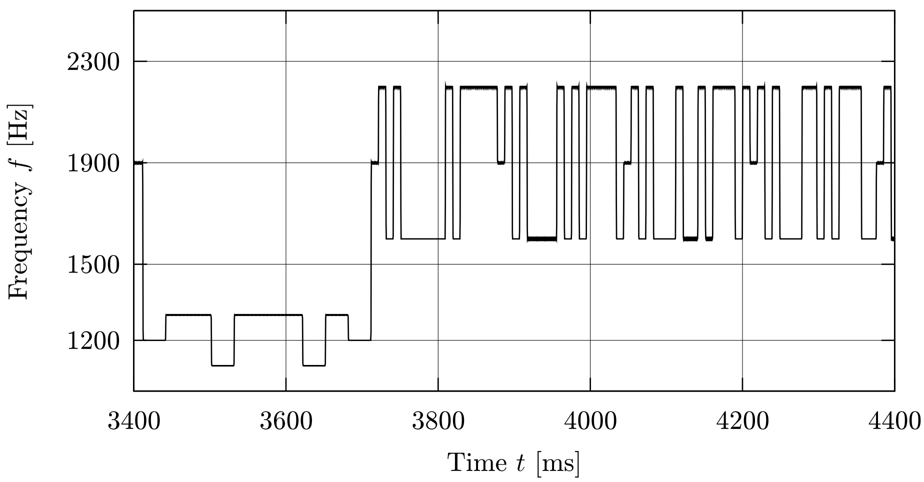


Figure 4.7: The digital synchronization header of AVT 90 mode (VIS 68, normal variant).

The first three bit of each 8bit word identifies the mode:

▷ 010 – AVT 24,
▷ 011 – AVT 94, AVT 188, AVT 125 BW,
▷ 101 – AVT 90.

The last five bits are used as a count down before image transmission. These five bits are important for an accurate set of image initiation and synchronization. They vary between all 32 binary combinations during transmission. At least one binary code must be properly detected. In the beginning, all bits are in 0 states with 1 in inverted parts. When the countdown starts, all five-bit sequences run (e.g. for AVT 24):

```
010 00000 101 11111
010 00001 101 11110
010 00010 101 11101
        ...
010 11101 101 00010
010 11110 101 00001
010 11111 101 00000
```

When the count down gets to zero, the image scan-lines are sent. AVT reception depends on the first eight seconds of synchronization, for some implementations without the ability to synchronize later. Although the AVT modes are quite reliable, noise could cause a loss of the whole image. Sometimes it is not possible to receive a digital header due to interference, even if the interference later disappears. However, the original AVT software was capable of image reconstruction in this case. Because the image data is completely synchronous, the data simply has to be shifted in memory until the RGB data is aligned correctly, and then the image comes out perfectly. Again, the AVT system provided means to hot reconfigure the data after the reception. So reception without/after sync header worked fine.

The earlier listed options for each mode can improve its performance. The first is the narrow-band transmission which uses a 400 Hz band from 1700 Hz (black) to 2100 Hz (white). With an appropriate filter, the resistance to interference can be improved with minimal loss of image quality. For instance; the 400 Hz wide CW filter can be used with a variable IF shift.

The second option is the “QRM mode”, where an entire image is sent interlaced. Within the first half of image transmission time, half of the scan lines (every odd one) is sent. Then the scan loops back to the beginning and sends the remaining half of lines (even lines). The fact that some of the distorted lines of the first field are interlaced with fine lines received from the second will improve the overall subjective impression of image quality. The original AVT software also contains tools for handy image improvement – it is possible to select distorted lines and the program will reconstruct them by averaging neighborhood lines. It is also is possible to shift the second field horizontally independently of the first field. This allows you to compensate if there is a significant multi-path delay in regard to the two fields.

In ATV implementations, the system can work well without these interactive tools. But in practice, especially on shortwaves where conditions change quickly; the second field could be phase-shifted and this causes the notable “toothy” edge of the picture. The QRM option can be combined with the narrow-band mode.

Mode name	Transfer time	Resolution	Color sequence	Scan line (ms)				Speed (lpm)
				Sync	R	G	B	
AVT 24	31 s	128×120	R–G–B	—	62.5	62.5	62.5	960.000
AVT 90	98 s	256×240	R–G–B	—	125.0	125.0	125.0	480.000
AVT 94	102 s	320×200	R–G–B	—	156.25	156.25	156.25	384.000
AVT 188	196 s	320×400	R–G–B	—	156.25	156.25	156.25	384.000
AVT 125 BW	133 s	320×400	Y	—	312.5			192.000

Table 4.6: The AVT scan-line timing.

4.2.6 Wraase SC-2

A later version of Wraase modes was first built in the newer converter SC-2 from Wraase Electronics. Again, it provides another variant of line sequential systems. The author dropped the sequence of colors used in the earlier SC-1 converter, so the colors are now sent in the order: red – green – blue. Additionally, there is only one horizontal sync at the beginning of each line, just as in the Scottie and Martin.

Unlike other systems, the RGB system in the SC-2 has one characteristic that distinguishes it from other conventional modes. Image transfer is achieved when the transmission time for the green component is equal to the sum of the transmission time of the red and blue components, i.e. the ratio 2 : 4 : 2 of R : G : B components. Between color components, short gaps are not sent.

As we already know that the human eye is most sensitive to green by more than 50 %. The remaining 50 % in SC-2 is split evenly between the red and blue components. Red and blue components are not processed for a differential signal. This color reduction is not visible on common pictures, but it may happen that some images (e.g. B&W mosaic) may lose color information. The system is less precise for color interpretation in comparison with YCrCb modes but better in tuning resistance. One disadvantage of color reduction is found when green shadows appear on the image in stations without precise clock timing.

This mode is preferable in comparison to YCrCb because bad tuning will only reduce the contrast or saturation, but the hue is not distorted. Occasional green shadows remain as a tax for reduced transmission time.

The Wraase SC-2 family just like all other systems also has four different modes. The SC-2 180 offers the best quality for three-minute transmission, and unlike the previous modes does not use the RGB ratio 2 : 4 : 2 and is, therefore, a faster alternative to the Scottie DX mode. The two-minute SC-2 120 uses the RGB format 2 : 4 : 2. The remaining two modes, SC-2 30 with 128 and SC-2 60 with 256 lines have about half of the resolution found in SC-2 120.

Mode name	**Transfer time**	**Resolution**	**Color sequence**	**Scan line (ms)**				**Speed (lpm)**
				Sync	**R**	**G**	**B**	
Wraase SC-2 30	30	256×128	R–G–B	5.0	58.0	117.0	58.0	249.600
Wraase SC-2 60	60	256×256	R–G–B	5.0	58.0	117.0	58.0	249.600
Wraase SC-2 120	120	320×256	R–G–B	5.0	117.0	235.0	117.0	126.175
Wraase SC-2 180	180	512×256	R–G–B	5.0	235.0	235.0	235.0	84.383

Table 4.7: Wraase SC-2 scan-line timing.

4.3 High resolution transmission

High-quality images consume a lot of memory but memory was very expensive in early computer systems. High-resolution images were a real luxury, but over the years memory has gotten cheaper, therefore modern SSTV systems now have modes for high resolution broadcast too.

4.3.1 FAX480

The synchronous mode was the first high-resolution mode. It was first implemented in the ViewPort VGA interface and software for IBM PCs in 1993. The old VGA cards with 256 kB of memory can hold an image with a resolution 640×480 with only 16 colors. This provides only grayscale images, so this mode is used for only B&W transmission.

The image resolution of FAX480 is 512×480 and the transmission time is 138 seconds. In the early days of high resolution transmission, the only way to transmit hi-res images was facsimile mode (see **chapter 11**). So the creator Ralph Taggart, WB8DQT called it FAX480, but compared with classic facsimile there are not many similarities.

The synchronization of the FAX480 is derived from the reference frequency of 4.0 MHz, and a time unit is 4 MHz/2048 = 1953.125 Hz.

Vertical sync is resolved as follows. In the first five seconds a rectangular frequency modulation of 244 Hz between the black (1500 Hz) and white (2300 Hz) levels is transmitted. This creates the APT[4] signal.

The tone 1500 Hz is transmitted for 4 time units ($4 \times [1/1953.125] = 2.048$ ms) and 2300 Hz for 2.048 ms too. This gives a frequency of an ATP tone also 244 Hz ($1/[2.048 + 2.048] = 244$ Hz). This sequence is then repeated exactly 1,220×. Originally the system did not use the VIS code, but the code 85 was later added.

Originally, vertical sync is followed by a phasing interval of 20 white lines. Each begins with 5.12 ms sync 1200 Hz (10-time units), but this interval is omitted in some implementations.

Now it's time to transfer the image itself. It is composed of 480 lines. Each line begins, unlike the facsimile, with 1200Hz sync with a length of 5.12 ms and then continues a scan-line with 512 pixels. The duration of the scan-line is $512 \times (1/1953.125) = 262.144$ ms.

According to the creator, the horizontal resolution of 512 points was selected just because the FAX480 operating software had a control menu to the left of the screen.

4.3.2 Pasokon TV

These synchronous modes were released with *Pasokon TV* interface from John Langer, WB5OSZ. These modes retain essential SSTV parameters. They also used color-coding to transmit the individual color components in the order of red – green – blue with the format 1 : 1 : 1.

There are three modes in the Pasokon system. They have different transmission times: 3, 5 or 7 minutes, so the image quality differs.

[4] Automatic Picture Transmission signal, see **section 11.2.1** .

Each mode has a default timing for scan-lines:

- ▷ Pasokon P3 ...4800 Hz
- ▷ Pasokon P5 ...3200 Hz
- ▷ Pasokon P7 ...2400 Hz

The scan-line starts with a sync pulse of 20 time units, then there is a 5 unit black gap followed by the red component. It has 640 units, so there is one unit for each pixel. There are 5 unit black gaps between color components and at the end of the scan-line before the sync of the next line. These gaps should help improve the detection of syncs.

Pasokon P7 has the best image quality and longest transmission time which takes nearly seven minutes. If we split such an image into four equal parts, the image quality of one of them would correspond to that produced by the Martin M1 or Scottie S1 modes. The upper 16 lines are used for gray scale and the remaining 480 for your the image itself.

There are also two other modes with 480+16 lines. The P5 has a transfer time of almost 5 minutes with lower image quality and the P3 runs fastest at three minutes with a horizontal resolution about half of a P7.

A potential disadvantage of these modes is quite a long transfer time, which makes it difficult to use on highly variable short-waves. For those who do not mind the long transmission times, it can be used for exchanging pictures on VHF.

Mode name	Transfer time	Resolution	Color sequence	Scan line (ms)				Speed (lpm)
				Sync	R	G	B	
Pasokon P3	203 s	320×496	R–G–B	5.208	133.333	133.333	133.333	146.56488550
Pasokon P5	305 s	640×496	R–G–B	7.813	200.000	200.000	200.000	97.70992366
Pasokon P7	406 s	640×496	R–G–B	10.417	266.667	266.667	266.667	73.28244275

Table 4.8: The Pasokon TV scan-line timing.

4.3.3 PD modes

PD modes are the result of a cooperation between Paul Turner G4IJE and Don Rotier K0HEO. The mode was first introduced in May 1996 and it was developed to improve image quality and especially to reduce transfer times in comparison with Pasokon TV.

For speeding up the transmission, YCrCb color coding is used in the 4 : 2 : 0 format. If you divide the total time between two syncs by four, the result is the actual time for each color component. The scan-line begins with 20.0ms sync, then there is a 2,080 ms gap of black, and the first luminance signal Y_1. It is followed by chrominance signals $R - Y$ and $B - Y$ without any gap. Then there is a second luminance Y_2. The exact timing of modes is:

- ▷ PD-50 – 286 μs/pixel
- ▷ PD-90 – 532 μs/pixel
- ▷ PD-120 – 190 μs/pixel
- ▷ PD-160 – 382 μs/pixel
- ▷ PD-180 – 286 μs/pixel
- ▷ PD-240 – 382 μs/pixel
- ▷ PD-290 – 286 μs/pixel

YCrCb color coding needs accurate signal tuning to prevent color distortion. Thanks to wide horizontal sync, it is possible to detect frequency deviation and compensate color distortion. There is also the gray scale on the top of the image for tuning detection.

The main advantage is reduced transmission time compared with RGB modes. The PD-290 mode supports a resolution of 800×600 and its transfer time is nearly five minutes, although at the cost of little color loss. Some modes have resolutions of 640×480, while PD-160 has 512×384. The fastest two-minute PD-120 has a worse image quality, but in many cases, it is still sufficient. Besides the five modes with high-resolution, the system includes two with standard resolution. PD-90 uses 320×240 and has a better image quality than Martin M1 or Scottie S1, because it is based on a longer transmission time per pixel. The last mode is the very fast PD-50, which provides a similar resolution as Scottie S2.

Mode name	**Transfer time**	**Resolution**	**Color sequence**	**Scan line (ms)**				**Speed (lpm)**
				Sync	$\boldsymbol{Y_{1,2}}$	$\boldsymbol{R-Y}$	$\boldsymbol{B-Y}$	
PD-50	50 s	320×240	Y-C	20.0	91.520	91.520	91.520	309.150866
PD-90	90 s	320×240	Y-C	20.0	170.240	170.240	170.240	170.687301
PD-120	126 s	640×480	Y-C	20.0	121.600	121.600	121.600	235.997483
PD-160	161 s	512×384	Y-C	20.0	195.854	195.854	195.854	149.176545
PD-180	187 s	640×480	Y-C	20.0	183.040	183.040	183.040	159.100552
PD-240	248 s	640×480	Y-C	20.0	244.480	244.480	244.480	120.000000
PD-290	289 s	800×600	Y-C	20.0	228.800	228.800	228.800	128.030044

Table 4.9: The PD modes scan-line timing.

4.4 Experimental modes

During the years of the SSTV boom many modes were created, but never gained popularity. Many of them are totally forgotten, like WinPix GVA, Proscan J-120, WA7WOD system or ScanMate, although some of them have a few interesting features which we are about to delve into.

4.4.1 MSCAN TV

The modes TV-1 and TV-2 were one of many experiments in the SSTV transmission field. An interesting feature is the use of *interlaced* transmission. They do not use the same half-frame interlacing like normal television does. But the whole image is divided into four quarter-frames. These frames are transmitted gradually in the direction from top to bottom, so you can get a first preview of the image after the first quarter of transmission time, but only in low resolution. Thanks to interlacing, the resolution increases gradually during transmission up to 320×256.

It is possible to receive these modes with conventional equipment without interlacing support, because of their line speed are the same as for Wraase SC-180 (TV-1) and Martin M1 (TV-2) modes. But in this condition, the image will contain four bars with all quarter-frames.

1. 2. 3. 4.

Figure 4.8: MSCAN TV image interlacing.

4.4.2 Kenwood FAST FM

This mode is built in the mobile SSTV converter *Visual Comunicator VC-H1* from Kenwood (see **section 6.7**). This unit support some normal modes and the "FAST FM" mode.

The FAST FM mode sends video signals in the 2800 Hz (black) to 4400 Hz (white) band. The vertical synchronization and VIS code format are similar to Robot's standard, it has a value of 90 but uses odd parity (the number of logical ones must be odd). After the VIS code there is a digital header and then an image with a resolution of 320×240.

The duration of one scan-line is 53.6 ms, so the total transmission time for an image is 13.5 seconds. The mode uses YCrCb color coding in the 4 : 2 : 0 format. The brightness signal occupies 35.4 ms of scan-line, and than there is a pulse of 3600 Hz that lasts 0.41 ms and then color signals are sent. Each even scan-line contains $R - Y$ and odd line $R - Y$. The scan-line is ended by 0.41 ms pulse again. The transmission of a whole image is ended by a one-second pulse of 1900 Hz.

Due to fast transmission, the used bandwidth of FAST FM is in 1.0 to 6.2 kHz range, so it cannot be used in the SSB voice channel, but only in FM channels on VHF. The image quality is comparable to the Robot 36 Color mode.

4.4.3 Modes MP, MR, ML

These modes were created by Makoto Mori, JE3HHT, the author of MMSSTV software. Some of these modes became quite popular, because of the success of MMSSTV. The author created modes with both standard and high resolutions. They use YCrCb colors and extended VIS code. Some modes use a narrower band for syncs and video signals.

Martin M1 MP115

Figure 4.9: The comparison of modes in real conditions on the 3.7MHz band.

The change he made to the traditional VIS specification extends the code by 8 extra bits, so a 16-bit code is sent instead. The first 8 bits (LSB) are the same for each mode with a value of 35 (0x23) that identifies the system. While the remaining bits (MSB) distinguish a particular mode. Odd parity is used as a simple check.

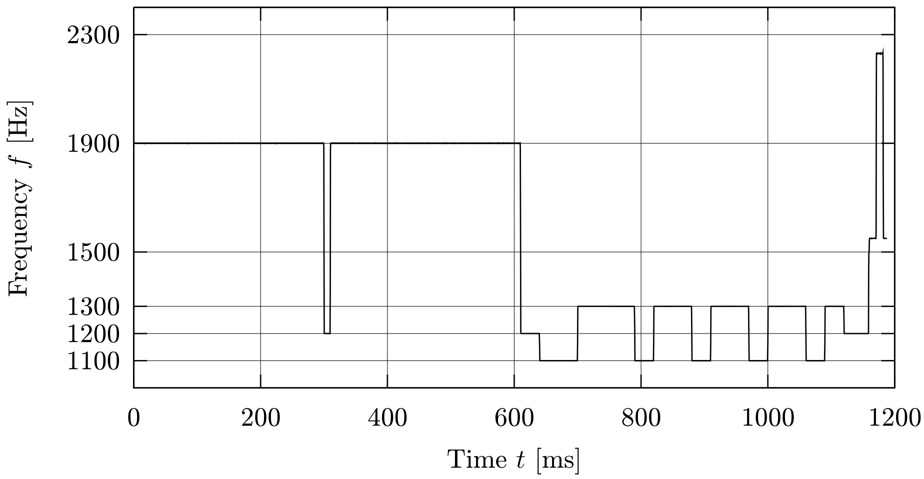


Figure 4.10: The 16-bit VIS code of MP115 mode with a 0x2923 value.

VIS used in narrowband modes has very little in common with the original standard. Initially, during vertical synchronization *N-VIS* pulses of 1900Hz and 2300Hz in 100 ms are sent, followed by a start bit of 1900 Hz (see fig. ??).

All code bits have a duration of 22 ms (modulation speed is 45.45 Bd). Logic one has 1900 Hz and logic zero 2100 Hz. The code word length is 24 bits and it is divided into four groups of 6 bits, bits are sent in the following order:

Each group has the following meaning:

- ▷ Group 0 (5–0) = 101101
- ▷ Group 1 (15–10) = 010101
- ▷ Group 2 (25–20) = N-VIS
- ▷ Group 3 (35–30) = 010101 `xor` N-VIS

For example, MP73-N has N-VIS = 000010 (0x02) and the whole code word is:

101101 010101 000010 010111.

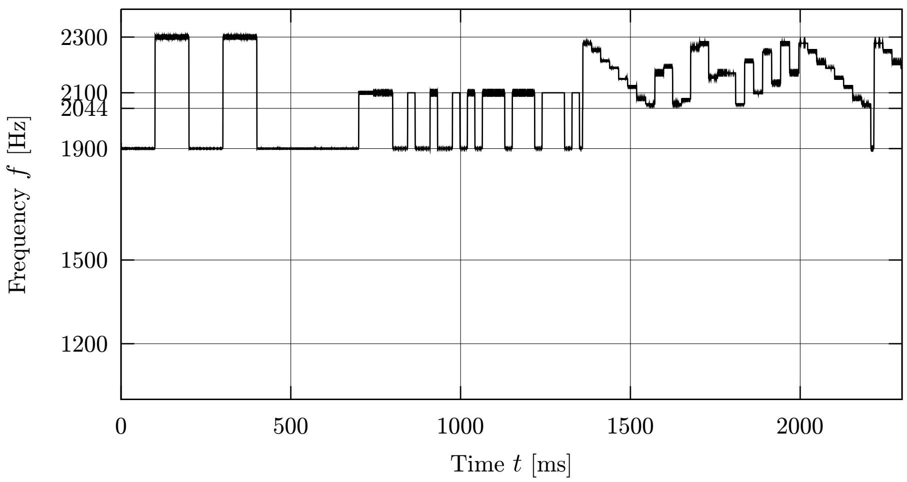


Figure 4.11: Vertical synchronization and scan-line of the MP110-N narrowband mode.

MP modes use the same principle as PD modes. The sync takes 9.0 ms followed by a short 1500 Hz gap of 1.0 ms, then odd scan-line Y brightness is sent followed by the $R-Y$ and $B-Y$ chrominance signals. The chrominance signals are the average of two neighborhood scan-lines. The scan-line is ended by the even Y luminance signal. This sequence is repeated 128×.

MP modes also have narrowband variants (MPxx-N) and their video signals occupy frequencies from 2044 to 2300 Hz.

The MR and ML modes use YCrCb color coding in 4 : 2 : 2 format, same as the Robot 72 Color mode. Horizontal syncs are the same as in MP modes. The scan-line begins with luminance Y, then 0.1 ms gap is sent followed by $R-Y$, a gap, and $B-Y$, the line then ends with a 0.1ms gap. These gaps should have the same frequency as the last pixel of the previous color component. The MLxx group has a high resolution of 640×496.

The MC-N modes are narrowband, but they use RGB color coding. Horizontal pulses last 8.0 ms and are followed by a 0.5 ms gap of 2044 Hz. The order of color components is red – green – blue.

Mode name	Transfer time	Resolution	VIS 16-bit	Color sequence	Scan-line (ms)				Speed (lpm)
					Sync	Y	R–Y	B–Y	
MP115	115 s	320×256	0x2923	YCrCb	9.0	223.0	223.0	223.0	133.037694
MP140	140 s	320×256	0x2a23	YCrCb	9.0	270.0	270.0	270.0	110.091743
MP175	175 s	320×256	0x2c23	YCrCb	9.0	340.0	340.0	340.0	87.591241
MR73	73 s	320×256	0x4523	YCrCb	9.0	138.0	69.0	69.0	419.140761
MR90	90 s	320×256	0x4623	YCrCb	9.0	171.0	85.5	85.5	340.618791
MR115	115 s	320×256	0x4923	YCrCb	9.0	220.0	110.0	110.0	266.489007
MR140	140 s	320×256	0x4a23	YCrCb	9.0	269.0	134.5	134.5	218.858289
MR175	175 s	320×256	0x4c23	YCrCb	9.0	337.0	168.5	168.5	175.361683
ML180	180 s	640×496	0x8523	YCrCb	9.0	176.5	88.25	88.25	330.305533
ML240	240 s	640×496	0x8623	YCrCb	9.0	236.5	118.25	118.25	248.292986
ML280	280 s	640×496	0x8923	YCrCb	9.0	277.5	138.75	138.75	212.276667
ML320	320 s	640×496	0x8a23	YCrCb	9.0	317.5	158.75	158.75	185.960019

Narrowband modes:

Mode name	Transfer time	Resolution	N-VIS	Color sequence	Scan-line (ms)				Speed (lpm)
					Sync	Y	R–Y	B–Y	
MP73-N	73 s	320×256	0x02	YCrCb	9.0	140.0	140.0	140.0	210.526316
MP110-N	115 s	320×256	0x04	YCrCb	9.0	212.0	212.0	212.0	139.860140
MP140-N	140 s	320×256	0x05	YCrCb	9.0	270.0	270.0	270.0	110.091743
					Sync	**R**	**G**	**B**	
MC110-N	110 s	320×256	0x14	R–G–B	8.0	143.0	143.0	143.0	137.142857
MC140-N	140 s	320×256	0x15	R–G–B	8.0	180.0	180.0	180.0	109.389243
MC180-N	180 s	320×256	0x16	R–G–B	8.0	232.0	232.0	232.0	85.166785

Table 4.10: The parameters of MMSSTV modes.

4.4.4 Martin HQ

The Martin HQ system from Martin Emmerson's workshop was released at the end of 1996. These modes were developed for Robot 1200C, SUPERSCAN 2001 and other compatible converters with the EPROM version 4.6, or 1.6. Unlike previous

Martin modes, they use YCrCb color coding. The transmission time of chrominance signals is half of the luminance (format 4 : 2 : 2). There are 6 signals sent between two doubled syncs. The first three signals create an odd scan-line: luminance Y, $R - Y$, $B - Y$. And the next three signals contain even scan-line: luminance Y, $Y - R$, $Y - B$. The opposite "polarity" of chrominance compensates for possible color distortion when signals are not tuned precisely. The HQ1 mode has 90 seconds for image transmission and HQ2 has 112 seconds.

Unfortunately, the author refused to disclose the exact specification of the system, so this improved system is not commonly found.

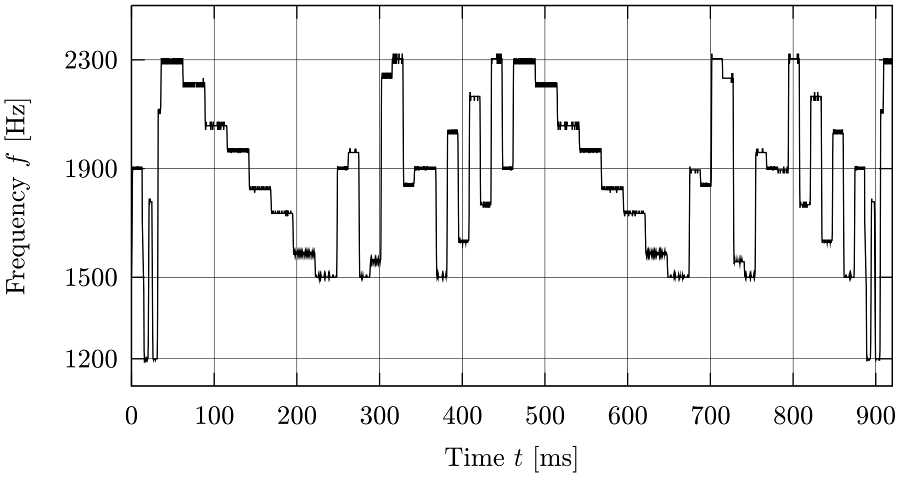


Figure 4.12: Two scan-lines of Martin HQ modes, when color bars are sent.