3

Modern SSTV features

A milestone between methods of old and modern SSTV image transmission is, without doubt, the usage of semiconductor memory chips. The creation of the first converters between fast and slow-scan television signals was credited to the existence of permanent image storage in memory. Consequently, image transmission could be improved because the usage of long persistence CRTs, which had been a major constraining fact, was now eliminated. Thanks to it, some new formats with longer transmission time were developed. They brought more quality to black and white transmission and helped to develop color image transmission.

There was a trend in the design of new formats that created several modes in each system. There were modes with faster transmission and lower resolution and on the other hand, modes for the transfer of higher quality images but longer time length. There is a possibility to change between them according to the actual band condition.

The early phases of development were influenced by two companies – the American *Robot Research Inc.* and the German *Wraase Electronic* led by radio amateur Volker Wraase, DL2RZ. Each of them introduced an SSTV converter that used each company's transmission system. The systems are different in the usage of color coding, scan line formats, and synchronization methods. Their converters provide several modes. *Mode* denotes a format of image transmission, its resolution, and transfer speed.

As often happens, the professional device did not fully satisfy ham radio users. So new systems with more modes were implemented into the converter firmware. And they were also re-implemented into other devices to ensure compatibility. Sometimes a new genuine system was designed to overcome imperfections found in the classic predecessors.

The number of those systems has grown unbelievably. Recently they were new systems created for better utilization of modern computer potentials. Modern personal computers with the necessary equipment, are full successors of SSTV converters. The advantage of computers is especially bigger memory and better image resolution.

If we were to count the number of all SSTV modes, we would find approximately 70! So it is possible to transfer SSTV images via seventy different modes, which are mutually different in transmission time, resolution, color coding, etc. The vast majority of them are unique and incompatible...

You might be a little scared by the previous paragraphs, but let me reassure you that only a few modes are actually used.

European amateurs widely used the SSTV mode called *Martin M1*, but in recent times other modes; *Martin M2* and *Scottie S2* are also in use. A special mode used *Scottie DX*; is characterized by the very high image quality. And the mode *Robot 36 Color* is undertaken in space communication.

Fortunately, all modern converters and computer software can operate with these popular modes, so the problem that two stations can not establish the QSO should not occur.

A digital vertical synchronization for automatic mode selection will be described shortly because every mode uses a digital header for its identification. Thanks to this any SSTV device can automatically switch to the correct mode and begin reception. Computer software also supports mode detection by measuring the elapsed time between two successive sync. impulses of image lines.

More details will be described in the following chapters.

3.1 Signal modulation

3.1.1 Bandwidth

Different communication channels, whether wired or wireless, have several characteristics, which define their behaviour in the transfer of effective signals. These include for example *attenuation*. Attenuation defines how much the communication channel reduces a transferred signal. Another important characteristic is the *bias*, which refers to the various distortions that occur due to imperfections within the communication path.

There are several negative influences, that affect signal transfer within a communication path. Their effects are not negligible. The intensity of this effect depends also on the frequency of the signal. Generally, it is always possible to identify a range of frequencies that a particular transmission path can transfer well and outside this frequency range the transmission is too poor.

The signal bandwidth does not depend only on the frequency range used for modulation, in our case 1,500 Hz to 2,300 Hz, but also on the signal spectrum.

Fourier analysis is used to determine the spectrum bandwidth. The analysis can express any waveform in the form of the sum of a large number of sine waves – harmonic components.

Limited bandwidth has the effect that the harmonic components lying inside this band will be transferred more or less without blemish and other harmonic components pass with a huge distortion or not at all (more in **chapter 7.2.1.1**, **page 2**).

Bandwidth can be seen as a characteristic of the transmission path given by the range of the signal spectrum.

The basic rule for the required bandwidth is called *Nyquist rate*. Its definition is that optimal bandwidth equals half of the modulation speed. The necessary bandwidth indeed increases with the amount of transferred information per time unit.

3.1.2 Modulation techniques of analog SSTV

An SSTV broadcast is usually carried out using single-sideband (SSB) amplitude modulation with a common ham radio transceiver. Frequencies above 2,500 Hz are strongly suppressed, so the frequency of white color, the maximal level of an SSTV signal, was chosen at 2,300 Hz.

SSTV signals are transmitted via frequency modulation of an audio signal. To avoid any phase shift and drift (which both have a negative impact on picture quality), the spectrum of the video signal is modulated on the auxiliary carrier frequency 1900 Hz – *sub-carrier*. This modulation method is called *Sub-carrier frequency modulation (SFCM)*.

The frequency of video signals varies from black by gray shades to white. The bandwidth needed for SSTV transmission varies in the range of 1.0 to 3.2 kHz and depends on the SSTV mode, transmission speed and also on image content, see **fig. 3.1**.

Cheap modems (based on Hamcomm) do not use perfect continuous harmonic signals, but also create the quantized signal. Step changes between quantization levels require wider bandwidth, so some image details can get lost.

The emission classification code for the SSTV mode is *J3F*, which means:

- ▷ *J* – Carrier modulation: Single-sideband with a suppressed carrier.
- ▷ *3* – Nature of modulating signal: One channel containing analog information.
- ▷ *F* – Detail of signal: television signals.

In the case of an SSTV transmission via a frequency modulated (FM) channel, the emission is classified as *F3F* and *A3F* for amplitude modulation (AM) with both sidebands.

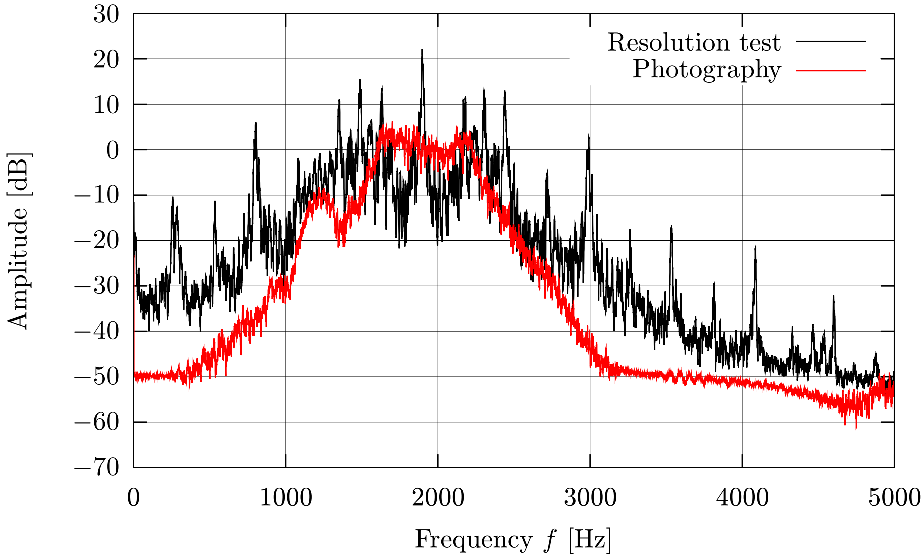


Figure 3.1: The SSTV frequency spectre for two various images transferred in Martin M1 mode.

50×38

120×90

Figure 3.2: Image quality depends on resolution.

3.2 Image resolution

Resolution is a feature that tells what amount of details is possible to store in an image, see fig. 3.2. The resolution has two parameters: *horizontal resolution* – the number of image columns × number of image lines – *the vertical resolution.*

In analog television technology, the more important parameter is the vertical resolution (number of lines) and it is defined by the selection of the SSTV mode. To get the horizontal resolution is more complicated.

As has been described in the previous text, the image is broadcast through the SSB channel on short waves and the maximal bandwidth is limited.

The SSTV is an *analog* mode and cannot transfer images without loss. The image is not exactly the same on the reception side as on the transmission side. Even if the communication channel is without any interference or noise, the image is still distorted due to transmission speed and limited bandwidth. The faster the transmission speed is, the greater the distortion result. Therefore it is very difficult to say what the horizontal resolution of an SSTV image is.

Most of the modes carry images with 240 lines and the image is displayed in a 4 : 3 aspect ratio on a screen. We can then say that the number of columns is $240 \times 4/3 = 320$. This value then corresponds to a theoretical resolution, but not a *real* image resolution.

The test chart (**fig. 3.3**) is used to qualify the horizontal resolution of images. The resolution pattern contains alternating stripes of black and white in various densities from very rough to fine. There is a comparison of this image with normal photography in **fig. 3.1**.

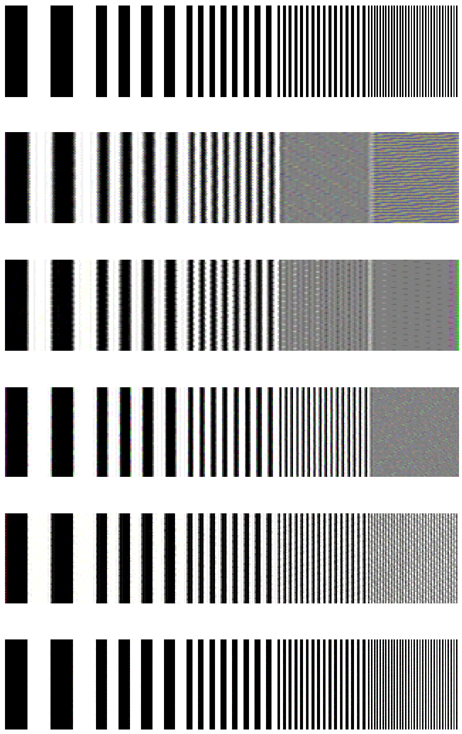


Figure 3.3: Horizontal resolution comparison for several SSTV modes.

All SSTV modes in **figure 3.3** have 320 columns. But as we can see, not all can transfer the image in actual quality. The note in brackets describes the approximate time needed for the transfer of one pixel. While with the Martin M2, we can hardly distinguish the second fine grid, the M1 mode with double transmission time can transfer it without problems, but its finest pattern is distorted. Compare it to the real picture in **fig. 3.4**. The last two modes listed have longer times of transmission and can transfer the finest details. Unfortunately, it is hardly compensated for by the slow speed of transmission.

Martin M1 Martin M2

Figure 3.4: The comparison of two modes in real conditions of 14 MHz band.

3.3 Line speed

One of the most important parameters that is suitable for SSTV mode selection is the total time required to transfer an image.

Due to present transmission speeds, SSTV is becoming similar to radio facsimile. Therefore, the mode parameters are not defined by horizontal and vertical scan rates, but in the number of lines transferred in one minute – *lines per minute (lpm)*.

Line speed depends on the selected mode and varies in the range from 57 lpm (Scottie DX), for high-quality transmission of color image (320×240) in nearly five minutes, up to 1000 lpm for BW image (128×128) in just 8 seconds. SSTV modes and their properties are described below.

3.4 Black & white transmission

For a black and white (BW) monochromatic image broadcast, only one signal is needed. It represents brightness/luminance Y of each image element.

The frequency ranges from 1,500 Hz (black) to 2,300 Hz (white) transmit image information. Each frequency in this range represents specific brightness – the level of gray.

Human vision can distinguish brightness in a wide range, but can only adapt to the geometric mean value of actual brightness. Around this value, about 100 to 110 grayscale levels can be differentiated.

Based on this fact; an ideal transmission could be regarded as 128 gray levels. At this figure, the average observer would not normally see transitions between adjacent grades.

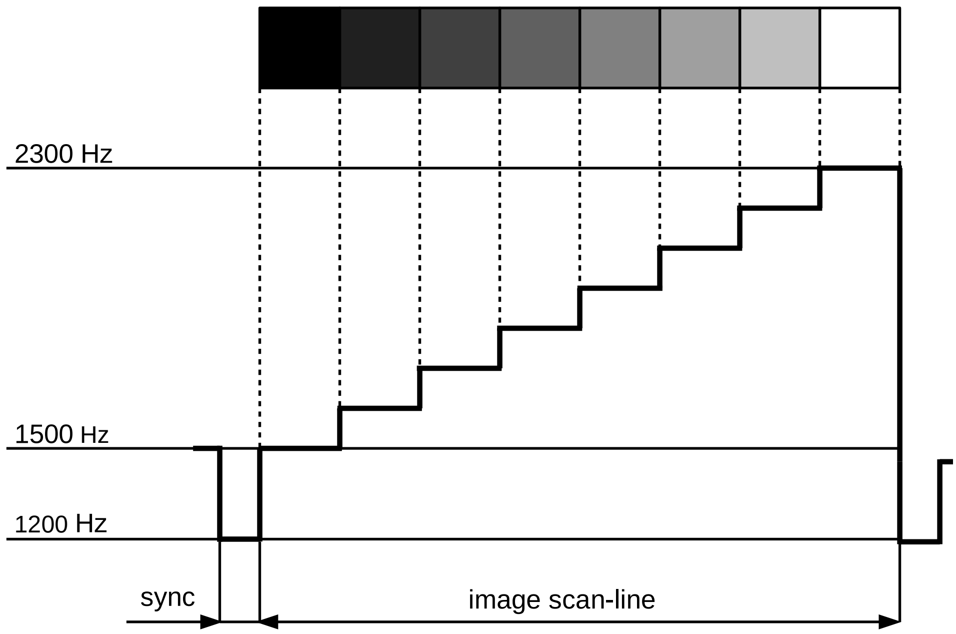


Figure 3.5: The scan line of BW image.

If we want to transmit images in 128 gray levels, this is the distance of signal levels 800 Hz / 128 = 6.25 Hz. The lowest frequency is for black and the highest is for white, the remaining 126 gray levels lay in the linear range between these two frequencies.

An issue with the transfer of more gray levels, for example 256 levels, is that it puts increased demand on the demodulator. The demodulator must be able to compensate for the frequency shift between the transmitter and the receiver. In this case, the distance between the two levels of brightness is 3.125 Hz and it is necessary to have a relatively large distance from the interference on the communication path, to assure a pure transfer of all grayscale.

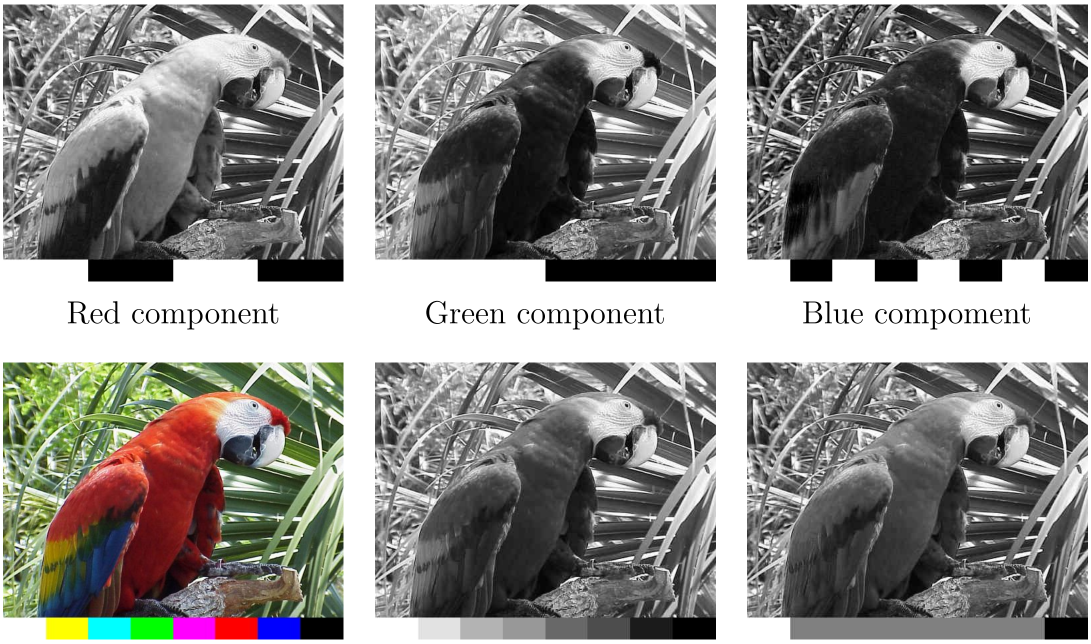
Normally, we can settle for a less bright resolution where it is possible to choose the transfer of only 64 levels. This requires less of the demodulator because it only needs to distinguish between 12.5 Hz steps.

True reproduction of color images in grayscale is another issue. Human vision cannot perceive the bright intensity of all three color components at the same time. When we watch three lights (red, green and blue) of the same intensity, the human perception considers the green light the brightest. Red and blue are not as bright in our perception.

But a BW television camera only scans the level of intensity, and therefore the resulting image would look like all the colors are the same. They will be characterized by the same gray-level depending on their intensity. Due to this fact, a valid grayscale image Y created from basic color components R, G and B (red, green and blue) is defined as:

$$Y = 0.30R + 0.59G + 0.11B$$

Note that the biggest factor 0.59 is just for the green, so nearly 60 % of colors that we can see depend on the green component and only 40 % is of the remaining color components! This is used for simplicity in color scan converters for BW images. In past years, BW images were not transmitted as true grayscale images, but the brightness signal was derived from the green component of the image. The difference in brightness between a true BW image and the green component of the same image is insignificant in most cases.



Red component Green component Blue compoment

True color image True grayscale Intensity

Figure 3.6: Decomposition of color image to basic components.

3.5 Colour transmission

3.5.1 Additive color model

Every color can be decomposed into three primary colors – red, green and blue. The additive color model produces other colors by combining these three primary colors.

During image transmission, the image is decomposed into these independent color components on the transmitting side. Then they are gradually transferred, and on the receiving side, the components are re-composed into a color image.

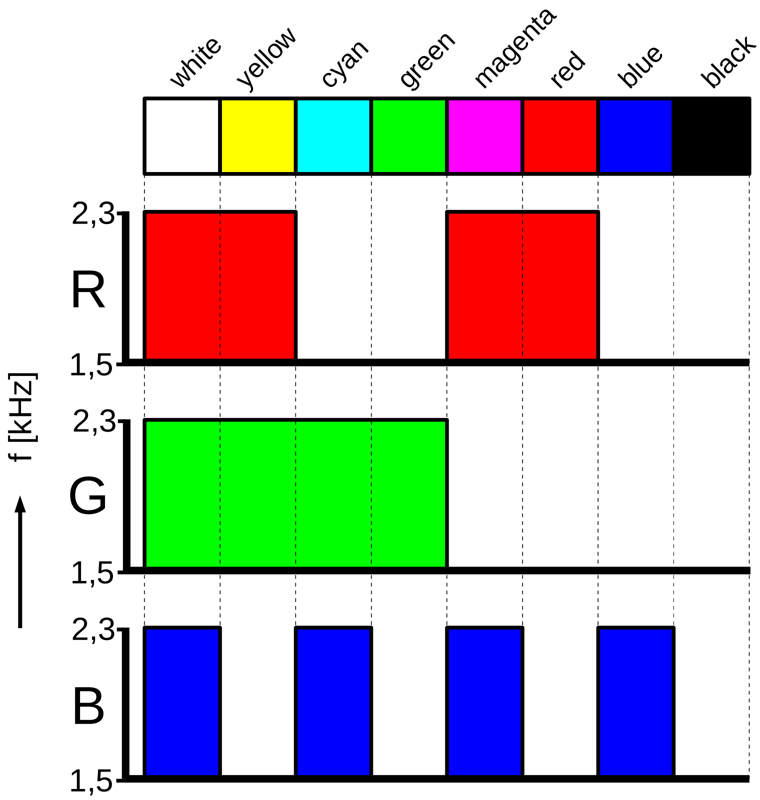


Figure 3.7: Decomposition of color image into RGB signals.

If it is possible to detect about 64 frequency levels in the 800 Hz video channel, then each color component contains 64 brightness levels. And the resulting color image then contains $64 \times 64 \times 64 = 256144$ colors. If a demodulator can distinguish

256 levels, it is possible to transfer over 16 millions = 256^3 colors. Colour SSTV transmission can meet the most demanding requirements of color depth.

Some color SSTV systems also use a property of human vision, which is a different sensitivity to the primary color components. In this case; the image scan-lines are not divided into three equal parts for each color component. Because the eye is most sensitive to green, the largest part of the line takes just this part and the remainder is filled with red and blue parts. For example, the ratio is $4:2:2$ for $G:R:B$.

The additive color model is a method of transmission that takes more time to transmit, but it provides a transfer of true colors.

3.5.2 Composite color model

The second type of color transmission is called *YCrCb*. In fact, it is a similar system as is used in color fast-scan television, where each color component R, G and B , are transformed to *luminance* and *chrominance* (color information) signals. Unlike RGB, the transmission time of an image is shorter. This color coding is used for BW and color compatibility in television broadcasts. In which color broadcasts can also be received by a BW television.

The image scan-line contains colors transformed into two components – luminance and chrominance. The chrominance signal is composed of two differential color signals $R-Y$ and $B-Y$. Signal Y is called *luminance* and contains the signal corresponding to brightness produced by the equation $Y = 0.30R + 0.59G + 0.10B$. The Y is for chrominance signals subtracted from the red and blue components.

On the receiving side, the individual color components are restored: $R = (R - Y) + Y$ and $B = (B - Y) + Y$.

We need a third green component the G, which is derived from $R-Y$ and $B-Y$ from the expression $G = Y - 0.51(R - Y) - 0.19(B - Y)$. Hereby we get complete color signals.

There are two formats of YCrCb color transmission used in SSTV. The first format $4:2:2$ transmits both chrominance signals (within half the time in comparison with Y) in one line. The second format $4:2:0$ contains only one chroma signal. Odd scan-lines could include for instance $R-Y$, and the even scan-lines could be $B-Y$. The chrominance signal is then given by the average of two consequent scan-lines of the original image.

The advantage of this type of transfer to RGB is significantly shorter transmission time. In comparison to RGB transmission, YCrCb takes approximately half the time yet guarantees almost the same image quality.

Its disadvantage compared with the RGB model, is a loss of image information which is higher when the $4:2:0$ format is used. Also, precise transceiver tuning is needed, otherwise the color information will be distorted. This is the reason why

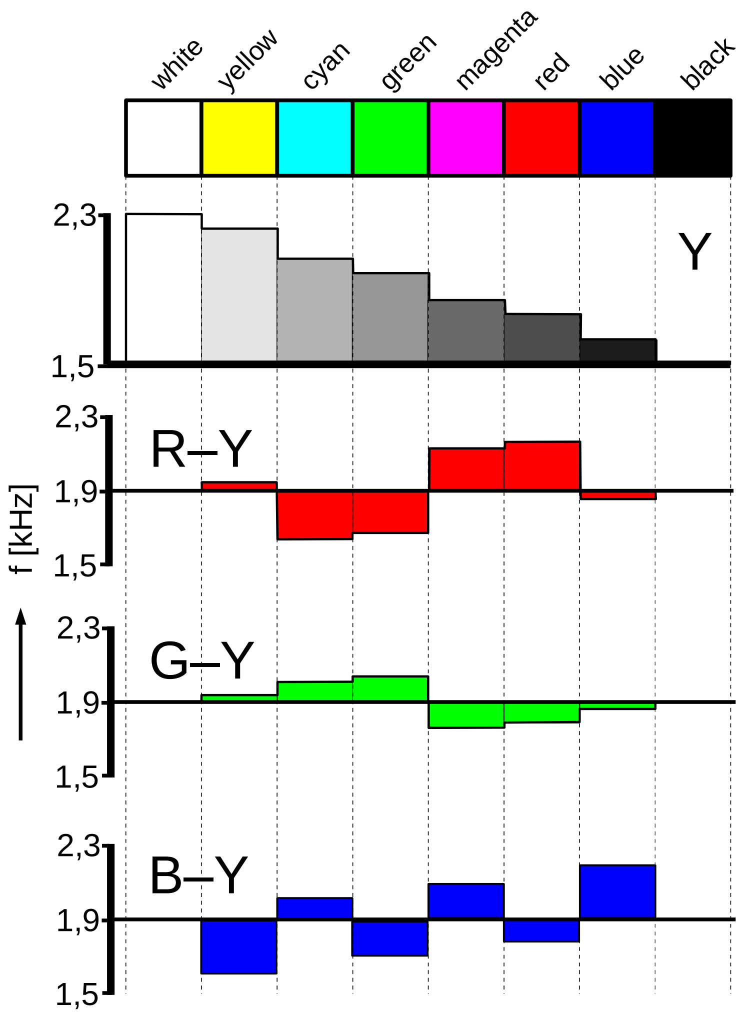


Figure 3.8: Decomposition of color image into YCrCb signals.

the YCrCb encoding is used less frequently. According to the positive or negative deviation from the carrier, the image is strongly hued to pink or green, see **figure 3.9**.

The transmission for color FSTV uses YCrCb and also uses special methods and modulation (in PAL, SECAM) to eliminate this color distortion, which can occur

Figure 3.9: Color distortion of YCrCb when the station is improperly tuned.

on the transmission path. Unfortunately, this feature does not exist in SSTV and so the result of selective fading[1] can cause color ghosts in the image.

SSTV systems using YCrCb transmission are less resistant to interference than their RGB counterparts, see **fig. 3.10**.

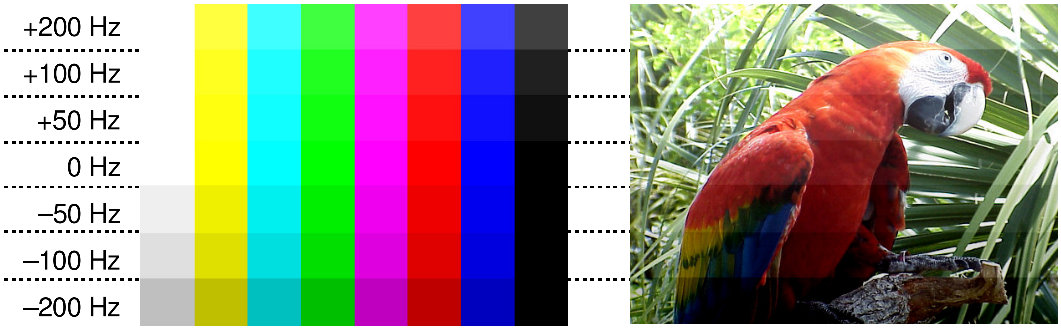


Figure 3.10: Color distortion of RGB when the station is improperly tuned.

The RGB model is distorted by a low contrast or increased brightness when there is significant deviation of ±200 Hz from the transmitter carrier and thus provides better colors than YCrCb.

3.6 Synchronization

3.6.1 Horizontal synchronization

There are two types of synchronization – *synchronous* and *asynchronous*.

[1] *Selective fading* is a phenomenon, where the signal comes from two paths, in which one signal path is the variable and causes instability of the ionosphere layers. It can be often seen in the 80 m band in the morning and evening.

Older SSTV systems use asynchronous transmission. This means that each information frame, in our case a scan-line, will be received after the detection of horizontal sync.

This system detects vertical (image) and horizontal (scan-line) syncs and only after proper detection will it display the received lines. The asynchronous transmission has a huge disadvantage. When interference happens close to the 1200 Hz frequency, an SSTV device can lose several scan-lines if interference remains.

In this respect, all new SSTV systems are improved and use synchronous transmission. These systems use *free-run* scan. It is not necessary to receive vertical sync and it is possible to begin reception from any scan-line. After the initial synchronization, it is not required to detect horizontal sync. Thanks to this, synchronous systems are much more resistant to interference. Scan-line syncs are still transmitted and then reception could start any time during transmission.

The disadvantage of the free-run scan is in complying with the very precise line speed of the corresponding parties. The line speed must be **absolutely** the same. If the values are different, there is an unpleasant effect on the picture – slant. For more information on this subject see **section 7.3**.

3.6.2 Vertical synchronization — VIS code

Vertical synchronization is used to detect the start of transmission. The receiving device can automatically begin the image scan after vertical sync.

The Robot Research company developed a new form of vertical synchronization called *Vertical Interval Signaling* – VIS. All modern SSTV systems adopted the VIS and use these longer syncs and digital headers for automatic SSTV mode recognition.

The VIS contains digital code, the first and last bits are the start and stop bits with 1200 Hz frequency. The remaining 8 bits provide mode identification and contain one *parity bit*. Each bit is transmitted in order from the least significant bit.

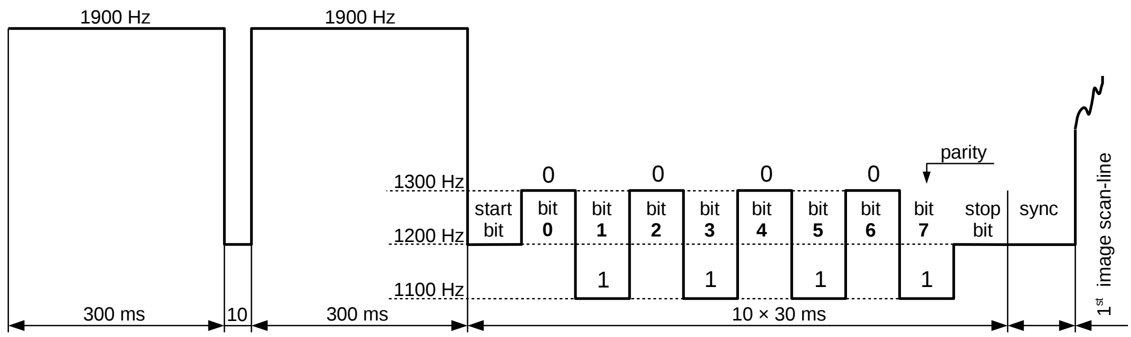


Figure 3.11: Structure of VIS with value 42.

Parity is used for simple error checking. SSTV use even parity. This means, that the number of logical ones must be even in the whole 8bit code. If the number of ones in 7 bits is odd, then the parity bit is set to one. If the number is even, the parity bit is zero. Since the information part of code has 7 bits, it takes 128 values.

Each bit is 30 ms long, so the modulation speed is 33.3 bauds. The frequency 1300 Hz means the state of logical zero and 1100 Hz logical one. The first half of code (least significant bits, LSB) specifies the type of mode (BW/color, resolution). The second half (most significant bits, MSB) contains information about the system (Robot, Martin, AVT,...). The last bit is reserved for parity error checking.

MSB				**LSB**				**Meaning**
P	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
						0	0	Color composite video
						0	1	BW, red component
						1	0	BW, green component
						1	1	BW, blue component
					0			Horiz. resolution 128 / 160 pixels
					1			Horiz. resolution 256 / 320 pixels
				0				Vertical resolution 128 / 120 lines
				1				Vertical resolution 256 / 240 lines
	0	0	0					Robot
	0	0	1					Wraase SC-1
	0	1	0					Scottie, Wraase SC-2
	0	1	1					Scottie, Wraase SC-2
	1	0	0					AVT, Scottie DX
	1	0	1					AVT, PD
	1	1	0					PD
	1	1	1					Pasokon TV
X								Parity bit

Table 3.1: The meaning of bits in VIS code.

The meaning of bits **table 3.1** is valid for a system based on the Robot Research standard. As the number of new modes has expanded, the bit combination has no additional meaning.

Mode	decimal	hexa.	binary
Martin M1	44	0x2C	0101100
Martin M2	40	0x28	0101000
Robot 36 color	8	0x08	0001000
Robot 72 color	12	0x0C	0001100
Scottie S1	60	0x3C	0111100
Scottie S2	56	0x38	0111000
Scottie DX	76	0x4C	1001100
Wraase SC-2 180	55	0x37	0110111

Table 3.2: The VIS codes of popular modes.

The comprehensive table of all VIS code is on **page 1**.

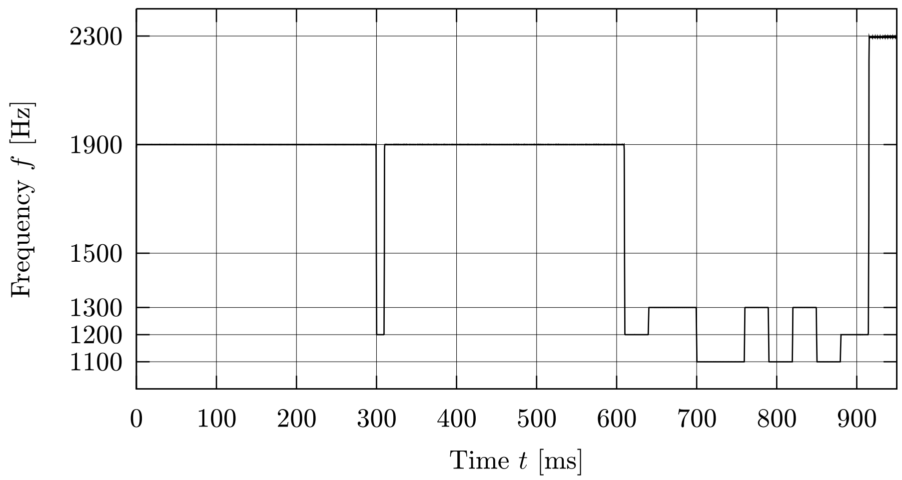


Figure 3.12: The vertical synchronization of Martin M1, the VIS code value is 44.

There is a vertical synchronization in **fig. 3.12** with a value of $\texttt{10101100}_2$ (44 decimal). The parity bit is `1`, and first three bits `010` distinguish the Martin system. The vertical and horizontal resolution can be determined from the value of the second nibble – `1` 256 lines and `1` 320 columns, the last two bits with value `00` mean color transmission.

3.6.3 Additional synchronization data

Some SSTV software appends a signal with additional data to the synchronization, e.g. call sign identification, which can then be decoded and used as an input for an electronic station log. Unfortunately, these additional signals have no standardized format and they are not compatible with other SSTV programs.

Some of them append the data transmission to the first scan-line image (ChromaPix) or even prior to the broadcast of VIS (WinPix, MMSSTV).

Some newly developed SSTV systems do not use standard VIS code with 8 bits and send 16 bits (MP, MR, ML modes) or use odd parity for error checking. This is because of 2^7, from which 128 possible combinations of the VIS code is almost exhausted. Differences in these and other systems will be described in further chapters.