UNIVERSITÉ de Picardie Jules Verne INSSET

CAL POLY SAN LUIS OBISPO

10th Annual CubeSat Developers' Workshop 2013
Cal Poly, San Luis Obispo – California – USA

Development of an SSTV camera (Use of a commercial product)

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Outline

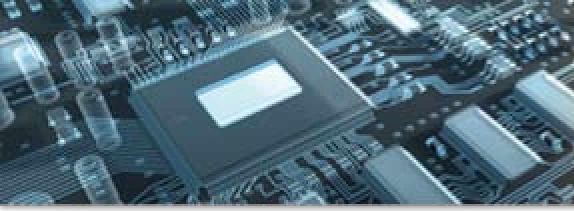
1. Institut Supérieur des Sciences et Techniques (INSSET/UPJV)

2. Sending images from space

3. Slow Scan TeleVision

4. Proof of concept

5. Conclusion



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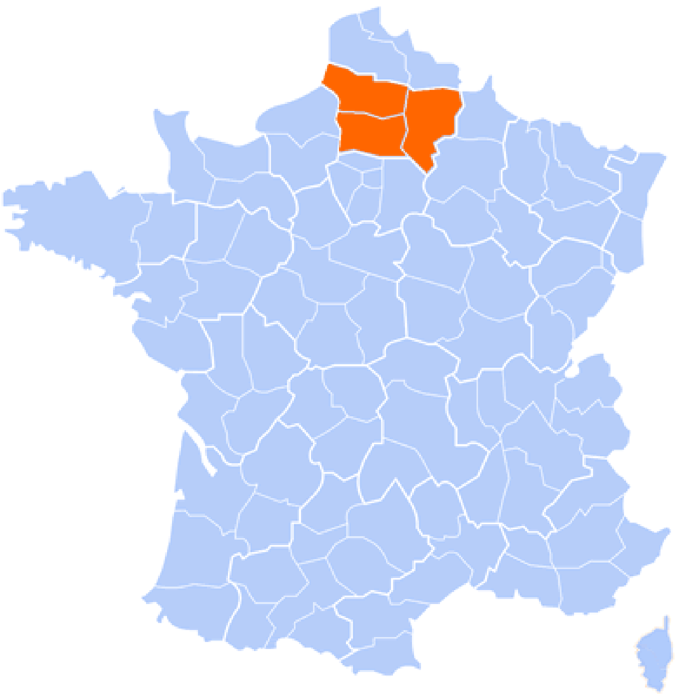

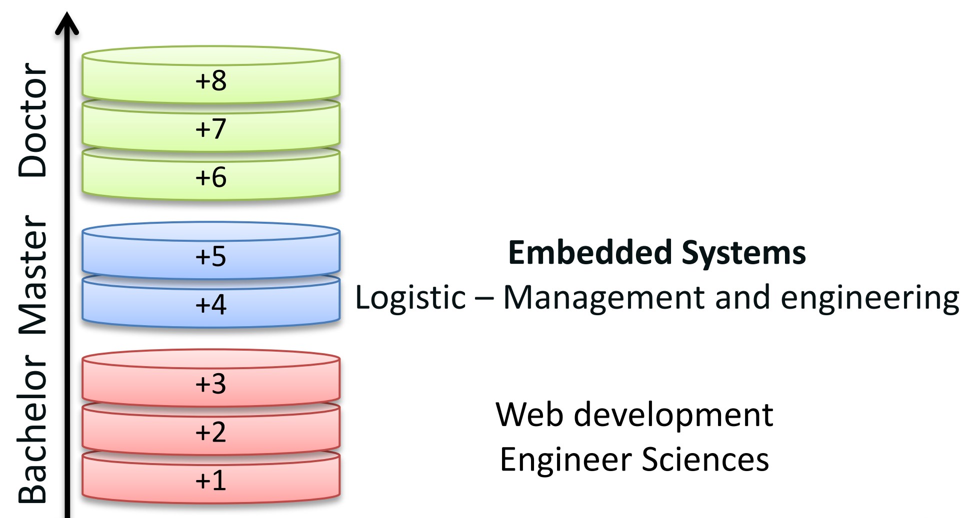

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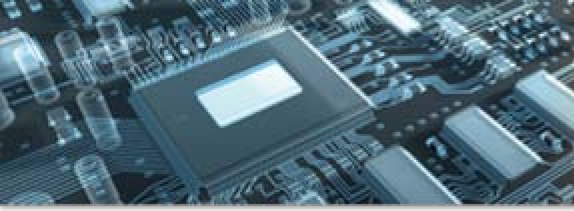


Platforms projects

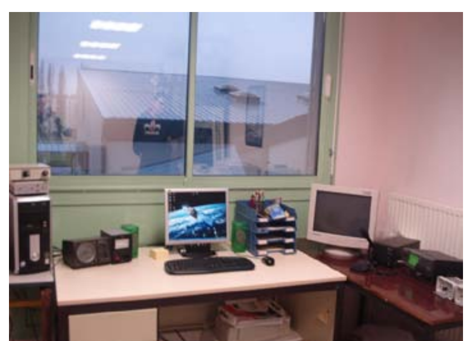
<u>We are mainly working on three different platforms :</u>

- **PRO.MO.CO;** *composed of a set of mobile robots built from autonomous software and hardware modules.*

- **The ground station (GENSO compatible)**; *for amateur radio and scientific data transmitted by satellites decoding, controllable remotely through the Internet.*

- **The CubeSat projects**; *based on the development of all the modules constituting a CubeSat and which the payload will include a scientific experiment and will handle video images transmission to different ground stations.*

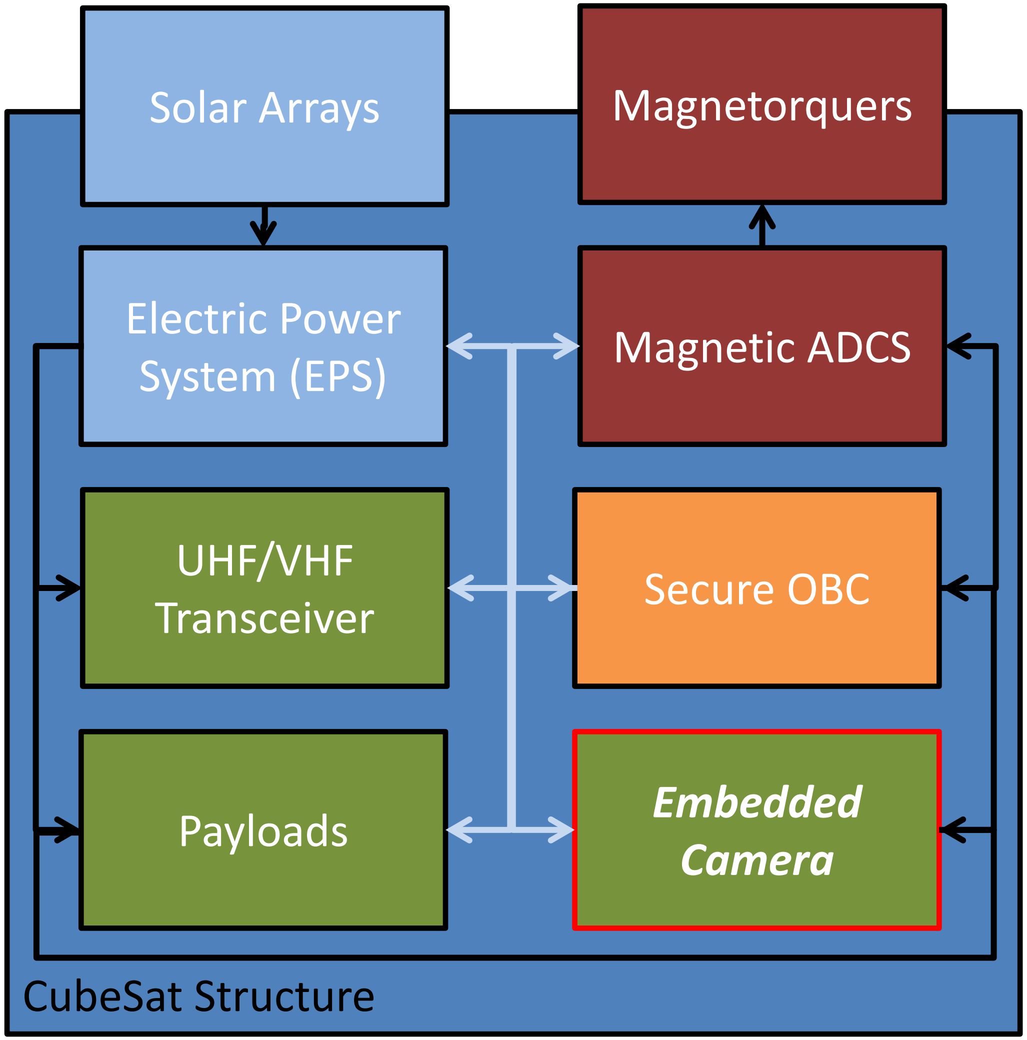
PRO.MO.CO platform

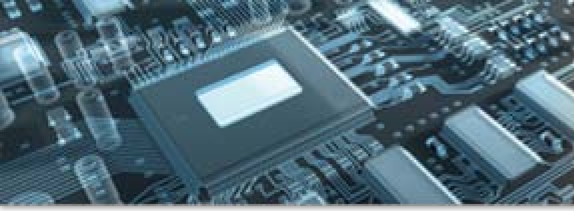


Ground station platform

CubeSat platform

CubeSat projects





Sending images from space

How to transmit images from space at low cost ?

<u>Requirements :</u>

- Low bandwidth
- Low radio transmit power (CubeSat)
- Basic chain of radio reception
- Best images resolution as possible
- Portable software on multiple targets

<u>Existing amateur radio transmission modes for images :</u>

- FSTV (Fast Scan TeleVision) or ATV
- NBTV (Narrow Bandwidth TeleVision)
- SSTV (Slow Scan TeleVision)

FSTV (Fast Scan TeleVision) or ATV

Advantages :
- Good image resolution (525 lines)
- Good speed transmission (Video transmission)

Inconvenients :
- Require high transmission power
- Require a large bandwidth (7 MHz)
- Require specialized equipment for emission and reception
- Susceptible to doppler effects (Frequency Modulation)

Incompatible with CubeSat applications !

Sending images from space

NBTV (Narrow Bandwidth TeleVision)

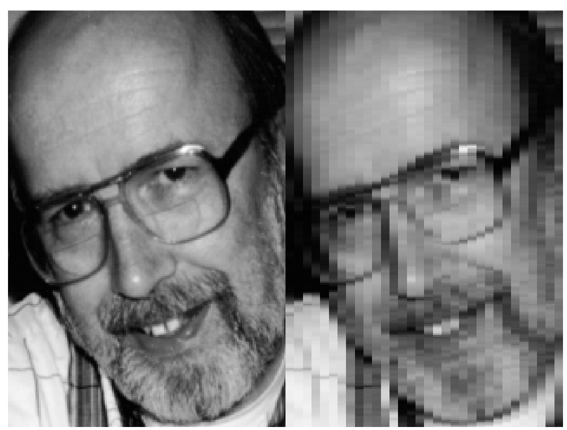
<u>Advantages :</u>

- No need of high transmission power
- Good speed transmission (Video transmission)
- Require a low bandwidth (2 kHz – same as audio transmission)
- Just require a computer for the restitution of the picture
- No need of specialized equipment for emission (same as audio transmission)

<u>Inconvenients :</u>

- Low image resolution (32 lines)
- Susceptible to fading (Amplitude Modulation)

Compatible with CubeSat applications but with low resolution !



SSTV (Slow Scan TeleVision)

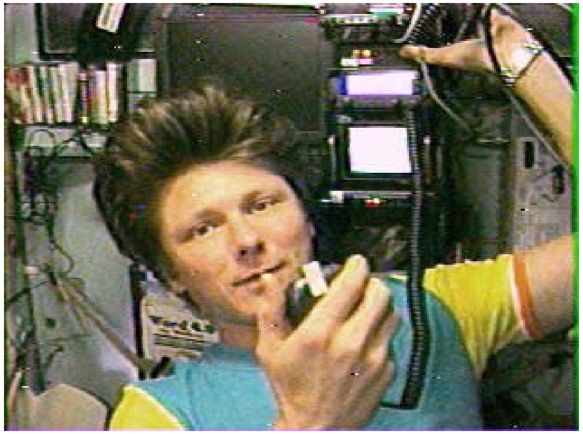
Advantages :

- No need of high transmission power
- Average image resolution (250 lines)
- Require a low bandwidth (3 kHz – same as audio transmission)
- Just require a computer (or smarphone) for the restitution of the picture
- No need of specialized equipment for emission (same as audio transmission)

Inconvenients :

- Low speed transmission (from 30 s to 4 min 30 s depending of SSTV format)
- Susceptible to doppler effects (Frequency Modulation)

Compatible with CubeSat applications !



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Slow Scan TeleVision

History

Concept :

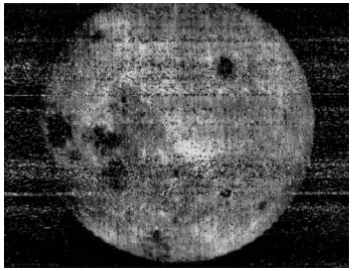
- Introduced by Copthorne Macdonald in 1957-1958
- Transmit images using a low bandwidth (3 kHz phone channel) in amateur radio context
- Black-and-white pictures with 120 lines by 120 pixels resolution

Usage at the beginning of space exploration :

- Transmission of images of the far side of the Moon from Luna 3
- A similar concept was used on Faith 7 as well as on the early years of the NASA Apollo program (resolution of 320 frame lines)

Current systems :

- Just use of a PC with special software in place of much of the custom equipment
- Color pictures with 256 lines by 320 pixels resolution

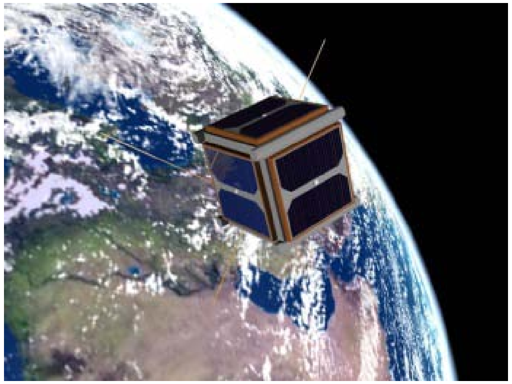


Far side of the moon

Apollo 11 first step

Modern SSTV picture

Transmission chain



CubeSat with camera and transmitter

Computer with decoding software

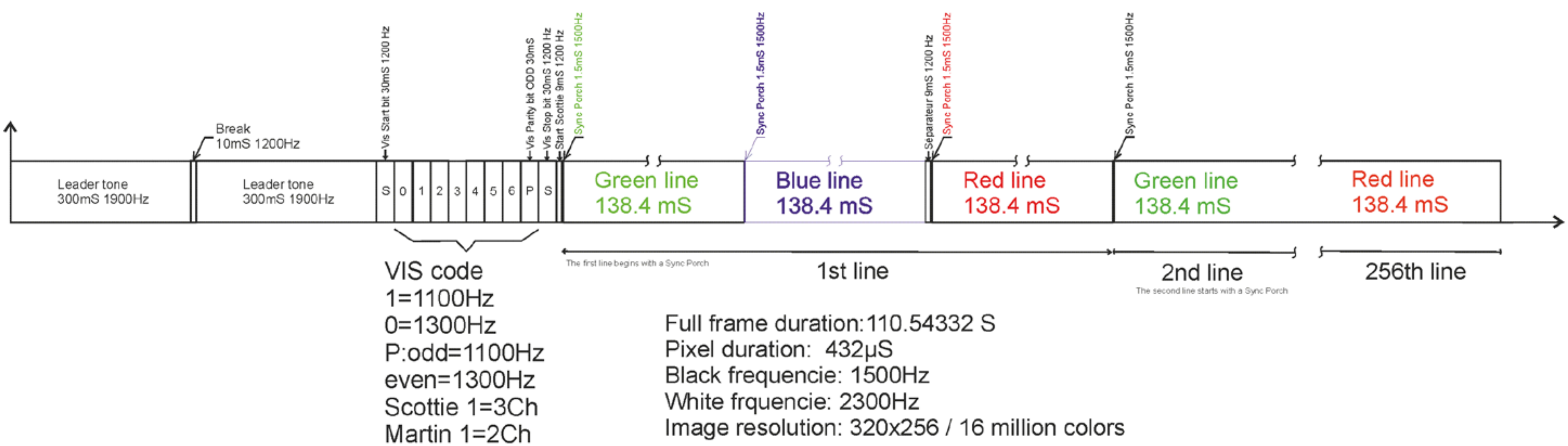
Big Wheel antenna

VHF receiver

Protocol

General description :

- A specific protocol with a very rigorous timing for frequencies generation
- Image is transmitted line by line on a low bandwidth (same as audio transmission)
- A frame start with a header which differs according to the protocol used
- Each line is then decomposed into its RGB components
- The frame header is composed by frequencies between 1200Hz and 1900Hz



Protocol

SSTV frame header :

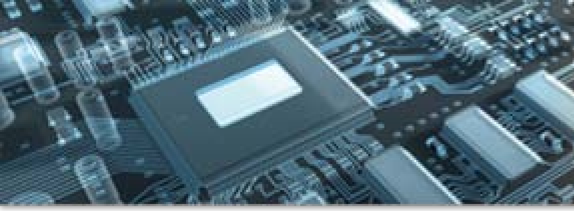
- All standard SSTV modes utilize a unique digital identification code (VIS code)
- The seven-bit code is transmitted least-significant-bit (LSB) first
- Followed by configuration of the parity bit

TIME(ms)	FREQUENCY(hz)	IDENTITY
300	1900	Leader tone
10	1200	break
300	1900	Leader tone
30	**1200**	**VIS start bit**
30	**bit 0**	**1100hz = "1", 1300hz = "0"**
30	**bit 1**	""
30	**bit 2**	""
30	**bit 3**	""
30	**bit 4**	""
30	**bit 5**	""
30	**bit 6**	""
30	**PARITY**	**Even=1300hz, Odd=1100hz**
30	**1200**	**VIS stop bit**

- Several protocols exist to transmit 256 lines colors pictures :

System	Mode	Colors	VIS code	Duration [s]	Lines	Columns
Martin	M1	RGB	44_d	114	256	320
	M2	RGB	40_d	58	256	320
MSCAN	TV-1	RGB	104_d	320	256	320
	TV-2	RGB	105_d	320	256	320
PD	PD 50	YCrCb	93_d	50	256	320
	PD 90	YCrCb	99_d	90	256	320
Scottie	S1	RGB	60_d	110	256	320
	S2	RGB	56_d	71	256	320
	DX	RGB	76_d	269	256	320
	DX2	RGB	80_d	136	256	320
Wraase SC1	48Q	RGB	24_d	48	256	128
	96	RGB	28_d	96	256	256
Wraase SC2	60	RGB	59_d	60	256	320
	120	RGB	63_d	120	256	320
	180	RGB	55_d	180	256	320

System	Mode	Colors	VIS code	Duration [s]	Lines	Columns
MMSSTV	MC110-N	RGB	20_d	110	256	320
	MC140-N	RGB	21_d	140	256	320
	MC180-N	RGB	22_d	180	256	320
	MP73	YCrCb	9507_d	73	256	320
	MP115	YCrCb	10531_d	115	256	320
	MP140	YCrCb	10787_d	140	256	320
	MP175	YCrCb	11299_d	175	256	320
	MP73-N	YCrCb	2_d	73	256	320
	MP110-N	YCrCb	4_d	115	256	320
	MP140-N	YCrCb	5_d	140	256	320
	MR73	YCrCb	17699_d	73	256	320
	MR90	YCrCb	17955_d	90	256	320
	MR115	YCrCb	18723_d	115	256	320
	MR140	YCrCb	18979_d	140	256	320
	MR175	YCrCb	19491_d	175	256	320



Protocol

We chose Scottie 1 mode (0x3C) for our proof of concept.
It is an American protocol and also the most used worldwide.

<u>Scottie S1 mode :</u>

- The first line only begins with an out-of sequence 9.0ms “starting” sync pulse, at 1200Hz
- The “regular” sync pulse is positioned between the blue and red scans

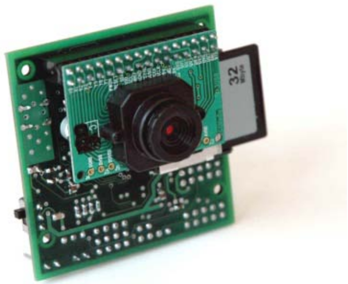
TIMING SEQUENCE

(1) “Starting” sync pulse (first line only!)	9.0ms	1200hz
(2) Separator pulse	1.5ms	1500hz
(3) Green scan		
(4) Separator pulse	1.5ms	1500hz
(5) Blue scan		
(6) Sync pulse	9.0ms	1200hz
(7) Sync porch	1.5ms	1500hz
(8) Red scan		

- The “regular” sync pulse is positioned between the blue and red scans
- After the first line, repeat steps 2-8 for following lines.
- The total duration for a complete image transmission is about 110.5 s
- Pixel clock of 432 µS
- Each pixel is represented by a frequency between 1500Hz (0_d) and 2300Hz (255_d)

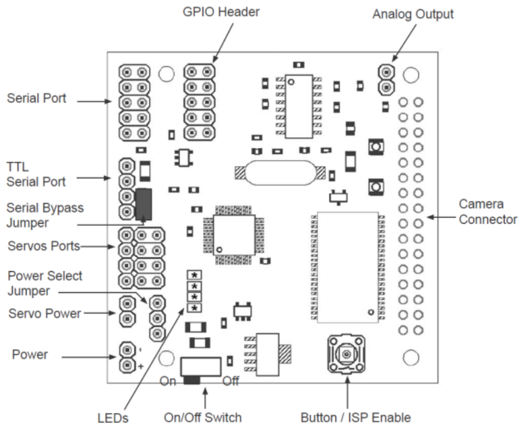
Material

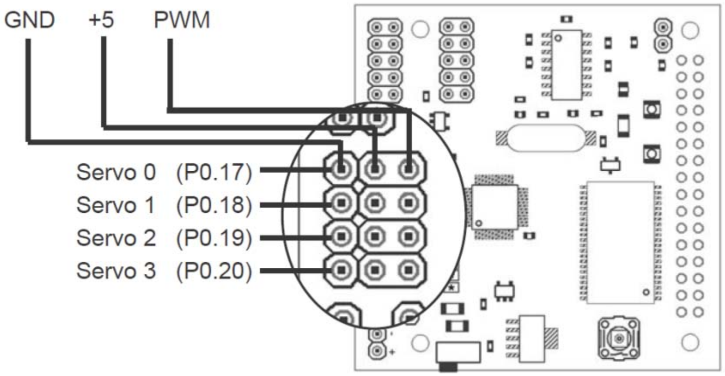
To validate the feasibility of the transmission, an approach was made using the "CMUcam3"



<u>CMUCam 3 :</u>

- Commercial electronic boad generally used for mobile robots (line tracking ...)
- Composed by an I2C camera
- Philips ARM7 microcontroller (Communication bus, GPIO, PWM, and others ...)
- Possibility to change the microcontroller firmware and thus implement new features



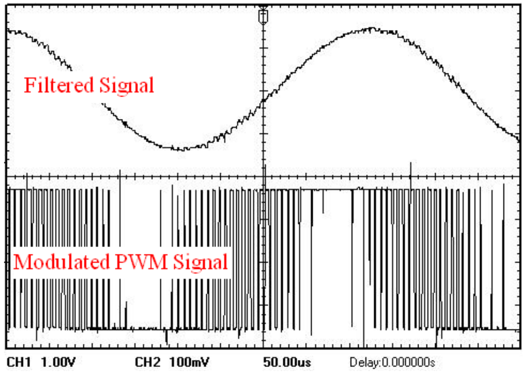


Proof of concept : Use of a CMUcam3

Implementation of the SSTV algorithm

<u>Frequency generation :</u>

- We modulate the PWM's duty cycle according to the sinus variation law
- A simple RC filter allow then to extract the sine and eliminate the PWM pulse



<u>Callsigns generation :</u>

- The 16 last lines of the picture are formed with the callsign of the transmitter
- A character table was created to determine the pixels to send to form the string

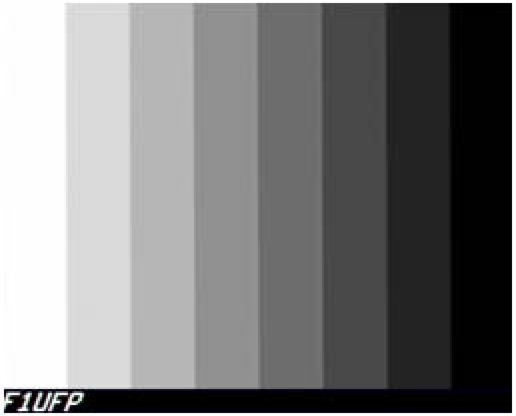
A

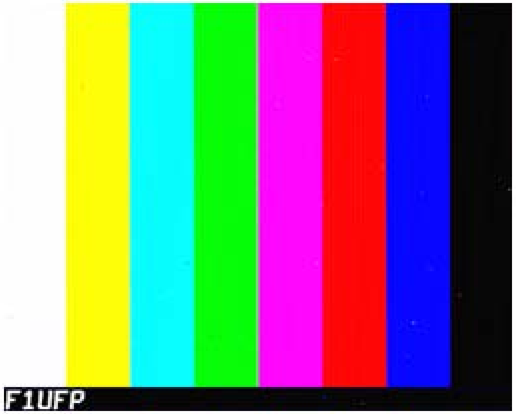
		1	1	1	1			60
	1	1	1	1	1	1		126
1	1	1			1	1	1	231
1	1					1	1	195
1	1					1	1	195
1	1					1	1	195
1	1	1	1	1	1	1	1	255
1	1	1	1	1	1	1	1	255
1	1					1	1	195
1	1					1	1	195
1	1					1	1	195
1	1					1	1	195

Proof of concept : Use of a CMUcam3

Validation of the SSTV algorithm

Test patterns :





Camera implementation :

Conclusion

- We developed an SSTV algorithm and test it with a CMUcam 3
- Our solution is just a software and is compatible with all ARM7 microcontrollers
- The use of a camera is not obligatory (possibility to send generated images)
- There are many possible evolutions in the future :
    - Add the possibility to store several pictures in memory to send it later
    - Implement other modes of SSTV transmission (Martin, MS Scan, …)
    - Implement an algorithm to generate images with informations provided by CubeSat (temperatures, power, solar panels states, etc.)

- We developed a derived product for amateur radio from FNRASEC (french civil security)
- Two functunalities was added :
    - ✓ Autonomous mode which sends images cyclically
    - ✓ Manual mode that lets us take photos at a button push


Conclusion

Thank you for your attention !