***Vladimir Tadić*** [67]
*Technical College of Applied Sciences, Zrenjanin/Serbia*
***Szabolcs Erdei*** [68]
*Faculty of Technical Sciences, University of Novi Sad/Serbia*

# CLIMATE CHANGE OBSERVATION WITH NOAA RECEIVING SYSTEM

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***Abstract:***
*This paper presents the results of a university project focused on observing climate control changes through weather map images. The project aimed to design, commission, and automate a receiver system capable of receiving signals transmitted by meteorological satellites. Signal reception is achieved using a two-element crossed Yagi antenna paired with a preamplifier. The received signals, originally in audio form, are then converted into images using specialized software. A Hilbert transformation was employed to facilitate the conversion process. The results of the project demonstrate that the automated system operates flawlessly. Furthermore, the system is not only effective for meteorological signal reception but also suitable for receiving other FM-modulated signals. The system consistently produces high-quality meteorological images.*

***Keywords:*** *NOAA, FM modulation, APT system, Image conversion.*

## Introduction

Thanks to technological advancements, it is now possible to create various circuits and electronic systems with relatively low financial investment, enabling their use in numerous applications.

The project described in this work is the result of a collaborative effort, where a radio system was equipped and put into operation with the equipment donated by Professor András Dr. Gschwindt from the Faculty of Electrical Engineering and Informatics (VIK) at the Budapest University of Technology and Economics (BME). The goal of the project was to study, understand, and bring the system into an operational state.

The continuous movement and signal transmission of satellites allowed for multiple experiments to be conducted daily. The primary objective of the project was to ensure that these satellite signals were automatically received and converted into images by the system. This capability opens up a variety of possibilities, such as displaying the

[67] vladimir.tadic@vts-zr.edu.rs, ORCiD: 0000-0002-8796-6822
[68] szabolcs.erdei123@gmail.com, ORCiD: 0009-0004-1783-5642

received images on a central projector, continuously updating the images on a website, and more.

The radio system's task was to receive signals transmitted by meteorological satellites. The recorded signals were processed using a computer running either Linux or Windows operating systems, along with appropriate software, to convert them into meteorological maps. These maps are invaluable for meteorological analysis and weather forecasting.

The collaboration was initiated by Dr. Vilmos Simon and Dr. Vladimir László Tadić. The equipment was generously donated by Dr. András Gschwindt, who also provided significant assistance in commissioning the system.

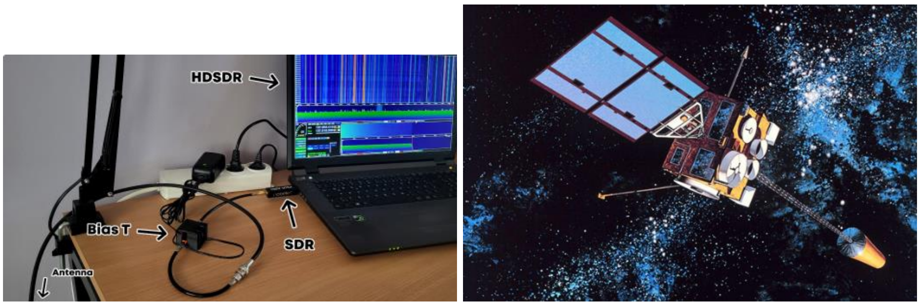
## 1. APT Systems and Meteorological Satellites

APT (Automatic Picture Transmission) is an analog image transmission system used by weather satellites since the 1960s. It continuously provides images to low-cost receiving stations worldwide [1, 2].

The transmission consists of two telemetry image channels (Video A and Video B) and synchronization data. NOAA POES satellites transmit 8-bit images with a spatial resolution of 4 km per pixel, captured by the AVHRR (Advanced Very High Resolution Radiometer) sensor. The images are geometrically corrected to compensate for distortions caused by Earth's curvature. One channel uses long-wave infrared (10.8 μm), while the other varies between near-visible (0.86 μm) and mid-wave infrared (3.75 μm), depending on sunlight conditions.

APT signals are AM-modulated with a 2400 Hz subcarrier and FM-modulated onto a 137 MHz RF carrier. The total bandwidth is 34 kHz, and transmission power is around 5 W. Receivers can capture images in real time while the satellite is within range (8-15 minutes).

To receive APT signals, a receiver with an appropriate bandwidth is needed. Traditional police and fire department receivers (15 kHz bandwidth) may generate black-and-white images. Modern VHF (Very High Frequency) receivers support bandwidths of 6 kHz, 15 kHz, 50 kHz, and 230 kHz. Too narrow of a bandwidth results in degraded images, while too wide of a bandwidth introduces excessive noise. Software-defined radios (SDRs) are the best solution for amateur users, enabling automatic reception with the right setup [3].




*(a)* *(b)*

***Figure 1.*** *(a) System during operation; (b) the meteorological satellite.*

Meteorological satellites monitor Earth's climate, tracking not only clouds and weather patterns but also pollution, environmental changes, ocean currents, wildfires, and other phenomena. Measurements are taken across various wavelengths of the electromagnetic spectrum, primarily in the visible and infrared ranges.

## 2. Required Equipment

The antenna consists of two crossed dipoles connected via a phase-shifting network, enabling true circular right-hand polarized signal reception. When signals arrive parallel to the surface, it functions as a linearly polarized antenna. As the elevation angle increases, the polarization shifts from linear to circular. This makes the KX-137 ideal for receiving signals from overhead satellites while minimizing signal loss.

A low-noise preamplifier with a high-Q filter is integrated into the antenna head. The high-Q filter enhances resonance and suppresses interference from nearby strong signals, such as aircraft or amateur radios. A passive reflector improves satellite signal reception and reduces surface-induced signal loss. To ensure optimal performance, the KX-137 must have an unobstructed line of sight to the satellites, typically by mounting it on a rooftop or elevated structure. This setup enables clear images from up to 5,000 km away [4, 5].

A Software-Defined Radio (SDR) replaces traditional radio hardware components with software, performing functions like amplification, filtering, and modulation via a computer. The system includes an analog-to-digital converter, allowing flexible adaptation to various radio protocols. SDR technology is widely used in military and mobile communication due to its ability to adjust to changing signals in real time. Over time, SDR is expected to become the dominant radio communication technology, enabling cognitive radios that dynamically select the best wireless channels while avoiding interference.


(a) (b) (c)

***Figure 2.*** *Equipment: (a) The KX-137 antenna system; (b) Nooelec RTL-SDR v5 device; and (c) Bias T Modul.*

**Specifications of the SDR used in this project:**

- RTL2832U demodulator / USB interface
- R820T2 tuner IC
- Ultra-low phase noise TCXO
- Shielded primary inductor & custom heatsink
- SMA antenna input
- Brushed aluminum housing

The Bias-T module is a compact diplexer circuit that filters radio frequency (RF) signals (0.2–180 MHz) while ensuring a clean and stable output [6]. It injects DC power into the RF signal to power remote antenna amplifiers via coaxial cables. The module consists of a feed inductor for DC power and a blocking capacitor to prevent DC from reaching the receiver. An internal blocking diode protects against reverse voltage damage.

**Technical specifications:**

- Frequency range: 0.2–180 MHz
- Insertion loss: 0.1 dB at 1 MHz, 0.4 dB at 100 MHz
- Max voltage: 30V, Max current: 3A
- System impedance: 50 ohms

Bias T circuits are commonly used to provide RF signals and DC power to remote devices.

## 3. Windows System Setup and Operation

The system runs on Windows 10 but is also compatible with Windows 7 and XP. Linux-based software alternatives are also available.

The first installed software is HDSDR, which enables:

- Signal detection
- Monitoring
- Recording and playback of received signals

HDSDR is one of the best SDR software options for Windows, offering easy installation and an intuitive recording/playback process. Key settings include:

- Mode selection (AM, ECSS, FM, LSB, USB, etc.)
- Frequency selection
- FPS and resolution settings
- Frequency zoom
- Bandwidth selection

WXtoImg converts recorded audio signals (e.g., from HDSDR) into images. Some configuration steps are necessary for proper operation:

- The audio file must be in .wav format
- Sample rate must be changed from 48000 Hz to 11025 Hz
- The file should be playable before processing.

Factors like recording time (day/night), weather conditions, and signal-to-noise ratio affect image quality. If settings are correct, the output image should be clear and detailed.

## 4. System Automation

The NOAA satellite reception system operates automatically, with satellite passes being the key factor. The Orbitron software tracks satellites overhead and signals HDSDR to start recording. These programs are linked via an easy-to-install driver that keeps the satellite signal in focus, reducing noise and improving image clarity. Orbitron also provides satellite data such as frequency, angle relative to the antenna, and real-time Doppler shift corrections.

**Automated Workflow:**

1. **Signal Reception:** NOAA 15, 18, and 19 satellites transmit signals, which the antenna captures and sends to Nooelec SDR for processing.
2. **Doppler Correction:** Orbitron adjusts frequency and bandwidth based on the satellite's position. The Doppler effect causes frequency shifts as satellites move relative to the observer.
3. **Audio Processing:** A Virtual Audio Cable (VBCable) transfers the signal to WXtoImg, which automatically adjusts the sample rate (from 48kHz to 11025Hz) and generates images.
4. **Image Calibration & Processing:** WXtoImg requires initial calibration for proper image alignment and brightness. After recording, the software automatically colorizes the originally black-and-white images, offering various display modes like climate highlighting and grayscale.

## 5. WAV File Conversion with Hilbert Transformation

The application allows the selection of a *.wav* audio file, then visualizes its signal and creates an image representation of the transformed signal using the Hilbert transform [7]. A graphical user interface (GUI) is provided to facilitate file selection, signal display, and image visualization [8, 9].

The key features are file selection, signal display, Hilbert transform and image generation, and image saving and display. With file selection, the user selects a .wav file using a file dialog, and its path is displayed. Signal display is used to read the audio signal and show it graphically within a specified interval. The Hilbert transform is applied to generate the signal's envelope, and the processed data is converted into a green-colored image representing the amplitude. The image is displayed and can be saved in PNG format.

**Implementation:**

- *PySide6* is used for the GUI, with file selection handled by *QFileDialog*.

- The audio file is read using *scipy.io.wavfile.read()*, and the signal is displayed via *pyqtgraph.PlotWidget*.
- A *scipy.signal.hilbert()* is used to apply the Hilbert transform, generating the envelope curve.
- The image is created using *PIL.Image* and displayed via a *QLabel*.

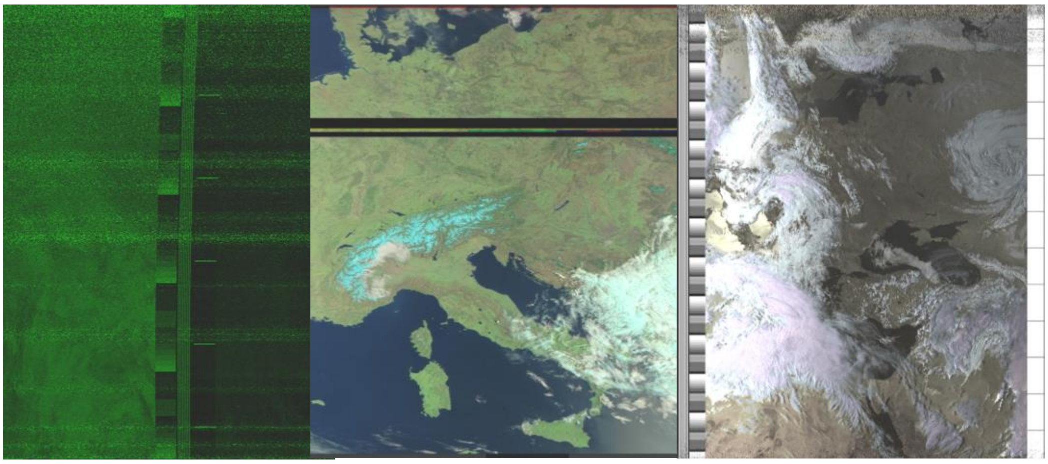


***Figure 3.*** *Results obtained using Python Code, Linux and Windows operating systems.*

This application efficiently handles *.wav* files, visualizes their audio signal, and generates an amplitude representation using the Hilbert transform.

## 6. Conclusion

This paper presented a radio reception system and its operation. The system runs on Windows and Linux and can also be controlled using Python. Multiple software tools were used for signal reception, conversion, and configuration, ensuring smooth operation and high-quality meteorological images. The Python code processes audio into images using the Hilbert transform.

Future plans include automatically transmitting the received maps over a LAN network to multiple laboratories and a central display system.

## ACKNOWLEDGEMENTS

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