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Research Article

Monitoring the Work of Small Satellites Using SDR Technology

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Abstract

A software-defined radio (SDR) system is a radio communication system that uses software to modulate and demodulate radio signals. A SDR is a general-purpose digital electronics device that conducts extensive signal processing. Because of its simplicity and ease of programmability, SDRs play an essential role in the evolution of wireless standards.

The goal of this paper is to construct and test a laboratory stand that can receive and monitor signals from small satellites. The primary goal is to include and demonstrate how SDR-based technology can be utilized on ground stations to lower production and deployment costs while replacing significant hardware components.

A variety of SDR-related issues are addressed in this thesis: software, hardware and the overall system. An optimal monitoring configuration may be determined by evaluating a variety of available solutions and tools. Information technology (IT) offers a wide range of software applications. In this case, ORBITRON and SDR Sharp are used. The hardware layer consisted of an SDR Sharp dongle with antenna sets.

The hardware of a software-defined radio typically comprises of a superheterodyne RF front end that transforms RF signals to analog RF signals, as well as analog to digital and digital to analog converters that convert digitized intermediate frequency (IF) data from and to analog form. At the moment, software-defined radio may be used to implement basic modem technology. SDR is expected to overtake other radio communications technologies in the next years.

Keywords: Image Processing; Satellite Communication; Signal Processing; SDR (Software-Defined Radio)

Abbreviations

ADC: Analog-to-Digital Converter; ADS-B: Automatic Dependent Surveillance-Broadcast; AOS: Acquisition of Signal or Satellite; APT: Automatic Picture Transmission; ASIC: Application-Specific Integrated Circuit; BW: Band Width; C/I: Carrier-to-Interference; CDMA: Code Division Multiple Access; COSPAR: Committee on Space Research; CPU: Central Processing Unit; DAC: Digital-to-Analog Converter; DDC: Digital Down-Converter; DDE: Dynamic Data Exchange; DLP: Data-Level Parallelism; DSP: Digital Signal Processing; DUC: Digital Up-Converter; EMI: Electromagnetic Interference; FFT: Fast Fourier Transform; FIR: Finite Impulse Response; FPGA: Field-Programmable Gate Array; FTP: File Transfer Protocol; GPP: General-Purpose Processor; GSP: Global Positioning System; HDL: Hardware Description Language; HDSDR: High-Definition Software Defined Radio; HPA: High Power Amplifier; HTTP: Hypertext Transfer Protocol; I/Q: In-Phase and Quadrature; IF: Intermediate Frequency; IFFT: Inverse Fast Fourier Transform; ILP: Instruction-Level Parallelism; JTRS: Joint Tactical Radio Systems; LDPC: Low-Density Parity-Check; LNA: Low Noise Amplifier; LO: Local Oscillator; LOS: Line Of Sight; MCX: Micro Coaxial Connector; MPSoC: Multiprocessor System on a Chip; MSPS: Mega-Symbols Per Second; NF: Noise Factor; NOAA: National Oceanic and Atmospheric Administration; NORAD: North American Aerospace Defense Command; ODMA: Opportunity Driven Multiple Access; OFDM: Orthogonal Frequency-Division Multiplexing; PPM: Parts Per Million; QPSK: Quadrature Phase Shift Keying; RF: Radio Frequency; SCA: Software Communications Architecture; SDR: Software-Defined Radio; SFDR: Spurious-Free Dynamic Range; SMA: Subminiature version A; SNR: Signal-to-Noise Ratio; SoC: System On a Chip; SR: Software Radio; SRC: Sample Rate Conversion; TCXO: Temperature-Controlled Crystal Oscillator; TLE: Two-Line Element; TLP: Task-Level Parallelism; UMTS: Universal Mobile Telecommunications System; USB: Universal Serial Bus; VFO: Variable Frequency Oscillator; VHDL: Very High-level Design Language; VRMS: Root-Mean-Square Voltages; YARD: Yet Another Radio Dongle

Introduction

SDRs (Software-Defined Radios) have been integrated into commercial radio equipment to improve efficiency, noise reduction, and digital filtering. SDRs use Digital Signal Processing (DSP) processors to execute standard analog radio functions at very high speeds [1]. The software flexibility offered by SDRs comes from their ability to adjust their operation, allowing the upgrade of new and improved functionality and a higher performance rate without the need to continuously change the hardware.

SDRs are also a low-cost way to obtain satellite tracking data and image reception, they are widely used in the production of pico and nanosatellites, also usually known as “small satellites” or “small-sats”. Small-sat platforms are generally educational and professional project innovations with educational and professional goals to plan, build, assemble, and operate them. The expense of these projects is typically minimal, SDR technology becomes a cost-benefit for the communication link. A rough estimation of how much SDR technology costs in comparison to fixed item equivalents is about 10%.

A SDR is a radio communication device where only standard components (filters, mixers, amplifiers, etc.) are instead implemented using software on a PC or embedded system. The primary benefit of this system is the provision of universal wireless connectivity, which enables end-users to communicate with anyone that they want, whenever they need it, in whichever way is necessary. Nowadays, the SDRs are continually changing. There is always a “last” model that shows up somewhere. here you can find the best of the most highly rated and common antenna SDRs. Here we have considered a variety of important factors for our list, such as cost, ease of use, application, and workable frequency range.

The following are some of the things that SDR can do that were not previously possible

- Software-defined radios can be reconfigured “on-the-fly”, which means that the universal communication system can adapt to its environment. One minute it might be a cordless phone, the next a mobile phone, the next a wireless Internet device, and next a GPS (Global Positioning System) receiver.
- Software based radios can be instantly and conveniently updated with new features. In reality, the upgrade could be delivered over-the-air.
- Software specified radios have the ability to chat and listen to several channels at the same time.

Aim and scope of the SDR technology

A software-defined radio (SDR) system is a radio communication system that modulates and demodulates radio signals using software. An SDR is a general-purpose device of digital electronics that performs large amounts of signal processing. SDRs play an important role in wireless standard growth, because of their simplicity and ease of programmability.

The aim of this design is to create a radio that capable of receiving and transmitting a new type of radio protocol simply by running new software. The primary scope of this work is to incorporate and demonstrate how SDR-based technology can be used on satellite ground stations to reduce production and deployment costs while replacing major hardware components.

A software-defined radio’s hardware usually consists of a superheterodyne RF front end that converts RF signals to analog RF signals, as well as analog to digital and digital to analog converters that convert digitized intermediate frequency signals from and to analog form, respectively. Currently, software-defined radio can be used to apply basic radio modem technology. SDR is predicted to become the leading technology in radio communications in the coming years. The following examples are available hardware platform of SDR in the present market [2-4].

The HackRF One SDR is used generally for a great radio with lot bandwidth. This model is capable of transmitting and receiving half-duplex transmissions. It is fully compatible with a wide variety of SR software applications. This model comes with an ANT500 antenna, four SMA (Subminiature version A) antenna adapters, and a USB (Universal Serial Bus) cable for setting up the system. This device can tune from 1 MHz to 6 MHz, which is quite a feat. For such a large spectrum of coverage. There is a lot of experimentation simply by shifting frequencies. If you buy two, you can also build your own radio protocols and apps, such as encrypted walkie talkies. You can also use the online GNU radio tool to build your own radios and instruments.

Uber tooth One is an open-source Bluetooth experimentation unit. It is powered by an ARM Cortex-M3 LPC175x processor and has a full USB 2.0 socket. The Uber tooth One is an outstanding tool for making customized class 1 Bluetooth applications. The gadget itself is just 6.5 cm long, with a USB-A connector on one side and an RP-SMA port for a 2.4 GHz antenna on the other. Uber tooth differs from other Bluetooth and SDR development systems in that it cannot only send and receive signals, but it can also run-in monitoring mode, monitoring Bluetooth traffic in real-time. This mode of operation has been available in low-cost Wi-Fi modules and has seen various applications in science, production, and security auditing, but there has been no such solution for the Bluetooth standard. Furthermore, since it is a truly open framework (both software and hardware), schemas and code are freely accessible for all developer needs.

The Great Scott Gadgets YARD Stick One (Yet Another Radio Dongle) is a palm-sized, low-speed USB wireless transceiver (similar to a Software Defined Radio or SDR) that can send and receive optical wireless signals at frequencies below 1 GHz. It utilizes the same radio circuit as the famous IM-Me. RF-Cat firmware is also pre-installed on the YARD Stick One. RF-Cat helps you to monitor the wireless transceiver from an integrated Python shell or your own computer software. YARD Stick One also includes the CC Bootloader, allowing you to update RF-Cat or mount your own firmware without the need for extra programming hardware.

RTL SDR is also a very small SDR that is only capable of receiving. With a nominal channel bandwidth of 2.4 MHz, the frequency band protected ranges from 0.5 MHz to 1.766 GHz. It is made up of a Rafael Micro R820T chip, a transceiver chip with a noise figure of 3.5 dB, and a digital modulator. This system has a tuning range of 500 kHz to 1.7GHz and a frequency of up to 3.2 MHz (2.4 MHz stable). This makes it suitable for use as a computer-based RF scanner with Android applications such as GQRX, HDSDR (High-Definition Software Defined Radio), SDR-Radio, SDR#, or SDR Touch.

The NESDR Mini 2+ is pre-tuned for SDR. This model has 0.5 PPM (Parts Per Million) TCX EO crystal GPS (Japanese fabricated), an RF-suitable voltage source, and improved parts. As a result, sensitivity has increased while power usage and noise levels have decreased. The kit contains a telescopic antenna, a magnetic suction base (to allow for other antenna mounting options), and a female SMA adapter in case SMA antennas are needed. Just be cautious about one thing. The antenna connector used with this box is a tiny MCX (Micro Coaxial Connector) female jack. As a result, if you are installing any system that uses SMA, make sure to first find any converter cables. The machine is designed around Rafael Micro's R820T2 tuner IC, which provides major performance improvements over the previous R820T IC model. This device's frequency spectrum is roughly 25 MHz to 1750 MHz. Since frequency varies from unit to unit, this is an approximation. Furthermore, the onboard RTL2832 (RTL2832U) IC serves as a USB port as well as the device's demodulator. In general, the NESDR Mini 2+ is an outstanding alternative for getting started with SDR devices. This model is also a low-cost radio for beginners, allowing them to experiment with fire and police searching, ADS-B (Automatic Dependent Surveillance-Broadcast), trucking, satellite imaging, and other related applications.

The Pluto SDR, which is specifically targeted at students, is yet another enticing choice. This gadget is a standalone full-duplex transceiver that can deal with signals ranging from 325 MHz to 3800 MHz at up to 61.44 MSPS (Mega-Symbols Per Second). You can also make small improvements to this system to get the most out of your investment. Next, you should widen the frequency spectrum to 70-6000 MHz and 56 MHz BW (bandwidth). Second, a second CPU (Central Processing Unit) core can be allowed. This one has a dual-core CPU, one of which is disabled by default. Pluto SDR is compact enough to fit in your shirt pocket when teaching SDR fundamentals, radio frequency, and wireless networking to students of all ages and backgrounds. Overall, this model is an outstanding alternative for any SDR enthusiast, not just students. This device's ability to transmit RF opens a whole new world of learning, and research.

The NESDR Smart incorporates the same ultra-low phase noise 0.5PPM TCXO (Temperature-Controlled Crystal Oscillator) used in our slightly smaller Nano 2+ (TCXO specs below), guaranteeing optimal tuning reliability in virtually every setting. In order to achieve lower noise, the power supply portion was revamped to have an RF-suitable voltage regulator with less than 10 VRMS (Root-Mean-Square Voltages) of noise. In order to improve EMI (Electromagnetic Interference) rejection, a high-quality shielded inductor was used in the power supply. The included aluminum cage keeps stray EMI where it belongs: away from the delicate RF circuitry. Lower board-level temperatures increase the SDR noise floor even further.

A compact SDR kit to go with your current USB On-The-Go compatible computers, the NESDR Nano 3 is a fantastic choice. This system is lightweight, simple to set up, inexpensive, and works perfectly. This RTL-SDR can be used for computers running Windows, Linux, and OS X in addition to Android (we suggest SDR touch). This model is not compatible with USB C devices since it is based on Micro-USB host devices. Because of its smaller size, this gadget can blend into narrow spaces without sticking out as much as other devices. This kit comes with a nano-sized antenna, four USB OTG adapters, a heatsink, and an articulating adapter for SMA antennas. The included Y-cable and Y-adapter allow an auxiliary power source to be attached to provide power to the SDR and extend the host device's battery life. The unit runs a little warm and can get a little warm to the touch. Despite this, the system stays stable throughout the process. Simply position this unit in an area where heat can quickly dissipate, and you should be perfect. Furthermore, the system comes with a two-year factory warranty. As a result, even though the system malfunctions or breaks, the investment is safe and stable.

Architecture of SDR devices

SDR plays an important role in wireless standard growth, Because of their simplicity and ease of programmability [1,3,5]. This is because the majority of digital signal processing and digital front-end operations, such as channel discovery, modulation, and demodulation, take place in the digital domain.

In general, from the viewpoint of the transmitter, shown in figure 1, a baseband waveform must be generated first, followed by an IF waveform. A radio frequency waveform will be produced and transmitted via the antenna. This RF signal is sampled, demodulated, and then decoded from the perspective of the receiver, as shown in figure 2. The RF signal from the antenna is amplified by a tuned RF level, which amplifies a frequency band spectrum. After that, the amplified RF signal is converted to an analog IF signal. This IF signal is converted into digital samples by the ADC (Analog-to-Digital Converter). It is then fed into a mixer stage. Another input to the mixer, which is an electrical circuit that takes two signals and produces a new frequency, comes from a local oscillator with a frequency set by the tuning control.

The mixer then converts the input signal to a baseband signal. The following stage is a FIR (Finite Impulse Response) filter, which allows only one signal. The FIR is made up of multiply-add and move registers. This filter functions as a decimating low-pass filter, limiting the signal bandwidth. In order to achieve the above functions, the digital downconverter requires a significant number of multipliers, adders, and shift-registers in the hardware. The signal processing stage then executes tasks including demodulation and decoding. This stage is usually performed by specialized hardware such as an Application-Specific Integrated Circuit (ASIC) or other programmable alternatives such as a microcontroller like FPGA (Field-Programmable Gate Array) or DSP.

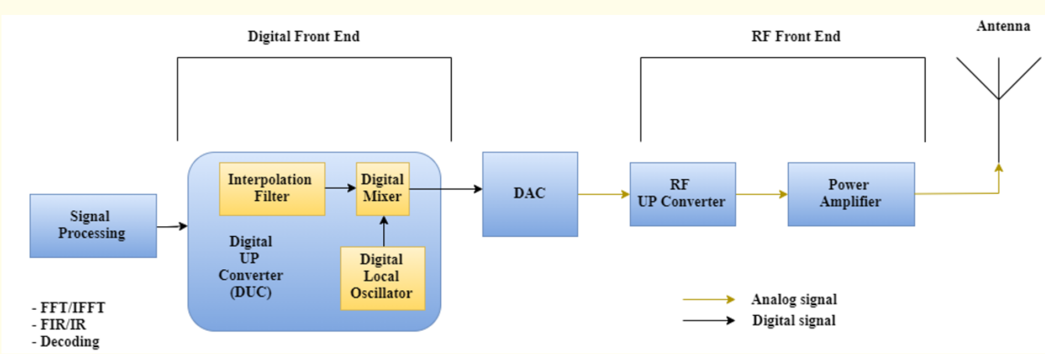


Figure 1: Transmitter block in SDR dongle.

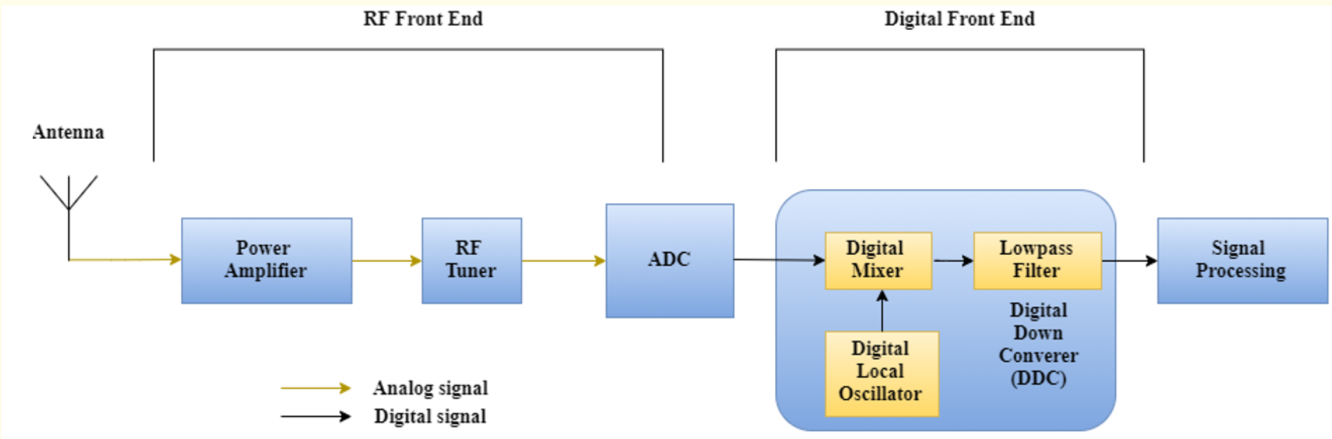


Figure 2: Receiver block in SDR dongle.

Antenna

SDR systems usually use multiple antennas to cover a broad variety of frequency bands. Antennas are sometimes referred to as "intelligent" or "wise" due to their ability to pick a frequency band and respond through smartphone monitoring or interference cancellation.

RF front end

This is an RF circuitry which primary purpose is to send and receive data.

At different operating frequencies, transmit the signal. It also serves another purpose. It also converts the signal to and from the IF. Based on the position of the signal, the operation is split into two stages.

The DAC (Digital-to-Analog Converter) in the transmission path converts digital samples into analog signals, which are then fed to the RF Front End. This analog signal is combined with a predetermined RF frequency, modulated, and transmitted. The antenna captures the RF signal in the receiving direction. To ensure optimum signal power transmission, the antenna input is connected to the RF Front End through matching circuitry. The signal is then amplified and the noise level is reduced by passing it through a LNA (Low Noise Amplifier) located near the antenna. This amplified signal is fed into the amplifier, along with a signal from the Local Oscillator (LO), to be down converted to the IF.

Analog to digital conversation and digital to analog conversation

The DAC is in charge of generating the analog signal that will be transmitted from the digital samples. The ADC, which is located on the receiver side, is a critical component of radio receivers. The ADC is in charge of translating continuous-time signals to binary-coded signals in discrete time. Various parameters can be used to characterize ADC efficiency. For example

- Signal-to-Noise Ratio (SNR): the ratio of signal power to noise power in the output.
- Resolution (bits per sample).
- Spurious-Free Dynamic Range (SFDR): the intensity ratio of the carrier signal to the next highest noise component or spur.
- Power dissipation.

Digital front end

The Digital Front End has two functions. SRC (Sample Rate Conversion) is a feature that transforms sampling rates from one to another. This is needed since the two contact parties must be in sync. Channelization requires up/down conversion on both the transmitter and receiver sides. It also involves channel filtering, which extracts frequency-divided channels. Interpolation and lowpass filters are two examples.

The digital front end of an SDR transceiver performs the following tasks

The Digital Up-Converter (DUC) on the transmission side converts the baseband signal to IF. The optical IF samples are then converted into an analog IF signal by the DAC, which is attached to the DUC.

The analog IF signal is then converted to RF frequencies by the RF up-converter. The ADC transforms the IF signal into digital samples on the receiving side. These samples are then fed into the next block, the Digital Down Converter (DDC). A digital mixer and a numerically operated oscillator are included in the DDC. The ADC's baseband digital signal is extracted by the DDC. This optical baseband signal is forwarded to a high-speed digital signal processing block after it has been analyzed by the Digital Front End.

Signal processing

This block performs signal processing operations such as encoding/decoding, interleaving/deinterleaving, modulation/demodulation, and scrambling/descrambling. The channel encoding acts as an error-correcting code. The encoded signal, in particular, contains redundancy, and is used by the receiver's decoder to reconstruct the initial signal from the distorted obtained signal. Convolutional codes, Turbo codes, and Low-Density Parity-Check (LDPC) are examples of error correcting codes. Due to data transfer and memory systems, the decoder is the most computationally expensive component of the Signal Processing block. The Fast Fourier Transform (FFT) and Inverse FFT (IFFT), as part of the modulation process, are regarded as highly complex and expensive in terms of area and power.

The signal processing block is also known as the baseband processing block. When addressing SDRs, the baseband block is central to the debate since it comprises the majority of the digital realm of the implementation. This implementation is built on top of hardware circuitry that can effectively process signals. ASICs, FPGAs, DSPs, GPPs (General-Purpose Processors), and GPUs are a few examples. The second component of the installation is the program, which includes the features and high-level abstractions used to carry out the signal processing operations.

State of the Art

SDR challenges

SDR challenges comprises three types of following challenges: Hardware, software and system challenges. The detailed view is described further in separate sections of this challenges.

Hardware challenges

As mentioned, following, the hardware challenges include analogue (front end), ADC/DAC, and digital domains (back end), specifically in wideband implementation.

RF front end challenges

The frequency-agile RF front ends that can simply be connected with the elements of the SDR that carry out the digital processing - whether pure software systems or a combination of hardware and software - have always been and continue to be a critical bottleneck in SDR. The SDR transceiver should be able to use any available band, adapt to numerous signals from different satellites and modulation techniques, switch between connections fast, and connect with two or more locations at the same time. It should have a broad dynamic range (to handle a huge interferer) while receiving the necessary signal at the same time. As a result, the RF portion must be extremely adaptable [6].

A well-designed SDR receiver [6] attempts for a balance of LNA noise factor (NF) (3dB) and good linearity (C/I > 50dB). The ratio of average received modulated carrier power to average received contiguous co-channel interference output is described as Carrier-to-Interference (C/I).

Nonlinearity is common in transmission system components such as voltage control. The modulation sidebands interact and cause various conflicting due to their nonlinear nature. Thus, intermodulation distortion inside the transmission system can cause interference, lowering the bit error rate at the receiver. Because SDRs may receive a wide range of frequencies, they are more prone to suffer from intermodulation distortions. This may be avoided by using thin digital filters around the SDR Technology for Simultaneous Multi-Satellite Connectivity signal of interest [6].

The system must have a high LNA and mixer linearity, suitable filtration, low LO phase noise and misleading signal production, and sufficient blocker resistance [6]. The important criteria at the transmitters are high power amplifier (HPA) linearity and low noise, which are required for low contiguous channel energy consumption, HPA efficiency and heat removal, and low filter insertion loss, which reduces power usage.

SDR's commercial use has been limited to offering "partial software upgradability" within a certain family of communication networks. This is owing to technological limitations at the RF front end, as well as its difficulty to be reconfigured.

However, using new advances in broadband RF front ends and soft transceivers, SDR can progress beyond "partial re-configurability" to "multiprotocol wideband re-configurability". Several developments at the RF front end and advancements in baseband process technology are already beginning to affect people's perceptions of SDR, such as putting the virtualization technologies as near to the antenna as feasible.

ADC and DAC challenges

The RF signal is translated into the digital environment as near to the antenna as achievable in an ideal SDR. The processing is performed in this manner via digital signal processing. As a result, in order to achieve the Nyquist requirements, the ADC requires a greater analogue input range and sampling frequency, for ex., To achieve the Nyquist requirements, twice the needed signal bandwidth. There is a trade-off between analog signal frequency and sample rate vs power consumption. Though electricity is not now a key barrier for the Ground Station, it would be in future space segment designs [6].

Baseband challenges

Furthermore, several techniques to baseband processing have been used throughout the last few years. The fast growth of semiconductor technology benefits the digital part of wireless terminals significantly. Computerization enables more complexity, gaining a competitive advantage and more connected features of electronic systems. As a result, electronic processors and their underlying software can easily meet the requirements of current multi-mode wireless systems [6].

The challenge in broadband architectural design with authentic restrictions is to

- Improve overall computational capability by handling wideband, high-bit-rate data within the CubeSat's allowable size, mass, and power restrictions.
- Adapt to difficult interference and noise situations by altering elements of the signal analysis in real time by loading latest software packages, while yet maintaining sufficient bit failure rates.
- Handle parallelism, network management, portability, and coding architecture difficulties in software design. There are three forms of parallel processing: Instruction-Level Parallelism (ILP), Data-Level Parallelism (DLP), and Task-Level Parallelism (TLP). Various types of parallelism are used by various SDR systems.

One of most typical way for a re-configurable broadband unit, also known as the software method, is to employ DSP processors, ASICs [8], and FPGAs [7]. Because DSP machines were perhaps the first to enable SDR, they are better suited to less compute complex kinds of data analysis rather than very high-speed tasks. They are frequently used for complex, off-line analysis of data that has been obtained and processed/stored by another type of device, such as an FPGA or an ASIC.

ASICs are usually tiny architectures that use few storage devices and consume little power. They may be used to create components like microcontrollers, main memory, and even SoCs. The main disadvantage of embedded ASICs is their long time-to-market and expensive start-up expenses. Furthermore, once the chips are made, the hardware structure cannot be changed.

In current history, both ASICs and FPGAs have undergone various changes in terms of quality and profitability. Although FPGAs employ a similar design concept to ASICs and accomplish the same functionalities, they provide the designer with increased flexibility, decreased design time, and the ability to reuse current solutions when designing innovative brands. Moreover, because of their natural redundancy, FPGAs are frequently employed to conduct computationally expensive digital signal processing activities, which fits the needs of SDR quite well.

System challenges

SDR design phase and execution involves the integration of several distinct disciplines, involving hardware, firmware, software, RF, DSP, and functionality as discussed:

SDR: high-level and low-level operations

Some implementations of SDR contain high-level processes such as signal attribute modification under computer control [9]. Others investigate its function at a much lower level, concentrating on how the core network function is performed. The first requirement applies to software-defined radio and, though this includes SDR, it is probably applicable to practically all current radio equipment. The other definition, on the other hand, is far more prescriptive, specifically defining what is intended by the word SDR.

SDR: field re-programmability

Another important aspect of an SDR is field re-programmability; software upgrades may be conducted "over-the-air" even without the interaction of the user [6].

SDR: dynamic changes in functionality

SDR is frequently identified as part of a radio that may dynamically change its operation to provide the best observed performance and spectrum utilization to the user. SDR systems, in particularly, have the ability to provide reconfigurable, multi-mode operational capacity. SDR supports signal detachment from the runtime environment, generally at the price of greater system complexity. Platforms based on system on a chip (SoC), multicore, and multiprocessor SoC (MPSoC) are ideally suited for such application due to greater system-level efficiency. Nevertheless, the difficulty here is to make the most use of the available resources while also optimizing the design. To fix this problem, Xilinx created SDSoC, a new C/C++ programming environment [9].

Software challenges

Digital signal is concerned with system identification, interpretation, and manipulation. Filtration, storage and rebuilding, informational extraction from noise, decompression, and extraction of features are all examples of signal processing.

Signal processing in communications networks is generally done at OSI layer 1, the physical layer (modulation, equalization, multiplexer, radio communications, and so on). The main purpose of signal processing in SDRs is detecting the frequency accurately and effectively in order to locate spectrum resources and share it without interfering with the other users, as well as filtration, predictions, and acquiring data and information.

Overall, of the years, different programming and technology techniques have been used to address these DSP issues. DSP algorithms has already used run on regular computers as well as specialized processors known as digital signal processors, which use software language like C/C++ and purpose-built technology such as ASICs. As of now, more effective multipurpose microprocessors, FPGAs, digital signal controllers (for mostly commercial processes such as motor control), and stream processors can be used for digital signal processing, with hardware description language (HDL) such as very high-level design language (VHDL) and Verilog playing an important role [10].

These languages are frequently preferable for applications with low capabilities that must be carefully maintained. They push you to think about and specify even the most minor features, such as memory allocation and threads. This low-level control may be used by a smart programmer to reduce the total amount in most higher-level applications. In that phase, one can use the target architecture or host system software attributes to boost performance. Nevertheless, there seems to be an invasion of DSP/Control frameworks such as MATLAB/Simulink and NI LabVIEW [11,12]. Programming is only one of a system designer's responsibilities in measuring and analysis application. Engineers frequently require more time needed to keep up with or update existing software to support changes in computer and measuring devices, operating systems, and so on.

They offer value by finding out how to obtain, process, and show actual data, not by inventing novel methods for managing memory allocations and thread pools. Building on top of validated, supported, and managed frameworks of lower-level code is possible with MATLAB/LabVIEW.

Table 1 compares two implementation approaches: those using custom/low level languages VHDL and those using a high-level GPP-based approach with several provided blocks (GNUradio). The "optimal" method is viewed as a middle ground between these two options [13].

VDHL	Ideal Platform	GNURadio
Cycle accurate	Real time	Soggy soft real time
Huge design effort up front	Ease of use for demodulator designer	Low design effort assuming block are available
Long design/ debug cycle (years)	Moderate design cycle months	Short design cycle days
Optimum resource and power utilisation	Good resource and power utilisation	Relies on huge CPU and memory resource
Very reliable	Good reliability	Moderate reliability

Table 1: Signal processing software options for backend process [13,14].

The challenge here is a lacking development support and decent information. The VHDL and GNUradio platforms both provide freely available components that may be utilized directly. They do, however, come with a significant cost since the blocks are overly general.

Designed of software defined radio system

A radio is type of device that uses infrared waves to transmit information remotely. Previously, a radio was made up of numerous discrete circuits and electrical components, and it had a set functioning that could not be changed once it was manufactured. A standard FM receiver, for example, could not be converted into a digital radio receiver using a standard radio. Therefore, using SDR, one may buy a USB DVB-T2 dongle built for satellite TV reception on a system and use it as a GPS system, or to decode ADS-B signals and acquire the locations of all surrounding aircraft. This demonstrates how, in terms of improvement and modularity, an SDR outperforms a regular radio. As per the Wireless Innovations Forum, SDR is a radio in which all or part of the physical layer operations are defined by software. The higher power of CPUs and FPGAs, the lower in price and utilization, and the introduction of numerous integrated RF transceiver circuits allowed this technique to improve recent times [5]. Figure 3 shows a simplified block diagram - Design of software defined radio system.

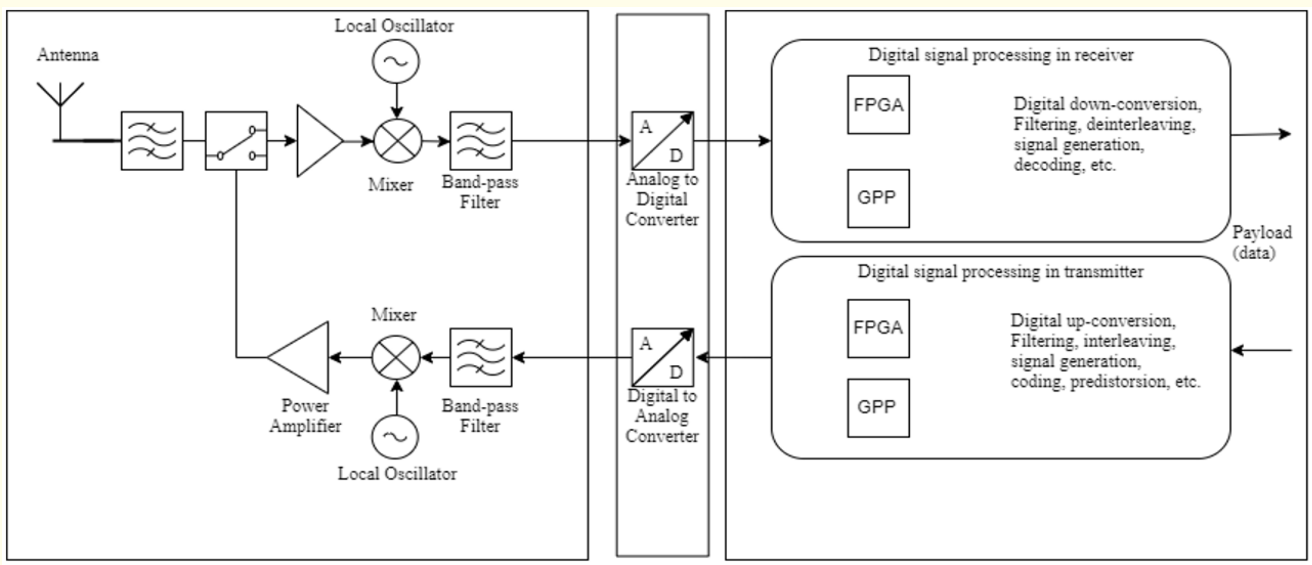


Figure 3: Design of software defined radio system.

In the middle part of the diagram, it has two types of converters. First type of ADC which converts actual analogue signals into digital and discrete signals, so digital circuit can process, and second type is Digital to Analog Convertor (DAC) that converts digital samples into an analogue waveform to feed the Radio Frequency (RF) stage, which prepares the signal for transmission by the antenna.

The last part of an SDR it has two different part digital signal processing receiver and digital signal processing transmitter. Both blocks have common feature that is GPP and FPGA. GPP, which handles all digital signal processing. As a result, because it is software defined, it is easy to change many features of a system's physical layer. Changing the software that runs in the GPP allows us to change the radio into a communication network. A SDR is regarded as an innovative solution for modern communication processes that support some form of reconfiguration capacity, such as adaptive or cognitive radio, due to the ease.

Standards and regulatory issues for sdr technologies

The software radio defined (SDR) forum

The SDR Foundation is a non-profit international group committed to helping the development, implementation, and usage of SDR technology in advanced wireless communication systems. Representatives of the group include software radio makers, telecommunications equipment manufacturers, silicon chip vendors, and scientific and research institutions. This Group is not a standards organization, but it does create suggestions that may become specifications in the future if enough business support is secured. The Organisation's work has helped to organize and produce technical standard requirements for various aspects of SDR technology.

Software standards for software radio

The software application of SDR/SR (Software Radio) systems is a key component of their functionality. Currently, efforts are being directed toward the creation of open software frameworks and interfaces with the goal of enabling software reuse, portability, and compatibility for these systems.

The United States Joint Tactical Radio Systems (JTRS) program created and promoted the Software Communications Architecture (SCA) specification, which has since become the most generally recognized architecture in the SDR/SR field. Figure 4 depicts the Software Communications Architecture's structure.

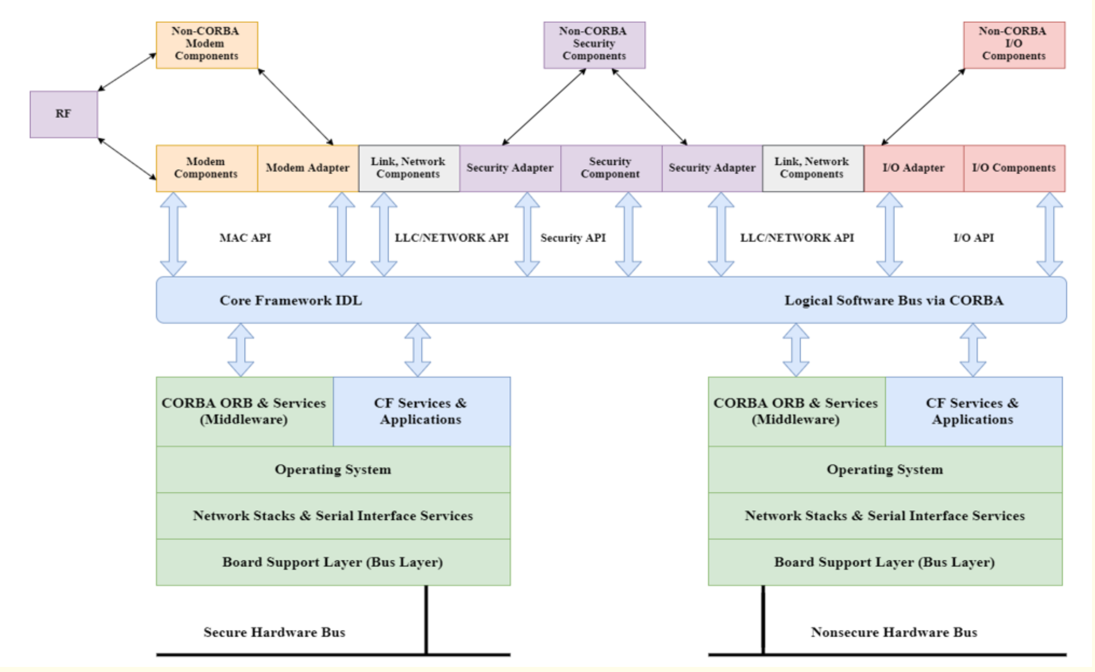


Figure 4: Software communications architecture.

The SCA (Software Communication Architecture) is a difficult and complicated architecture that allows the security and integrity of signal processing software on heterogeneous and distributed hardware. It also provides services for waveform generation, installation, monitoring, and removal, as well as distributed hardware monitoring, file systems, and system component configuration. For the future perspective the SDR/DR system will mostly use this architecture. because to the takeover by specified contractors in several nations and the creation of commercial and open-source software products based on it.

Required hardware and software application

Signal processing hardware components

As the next generation in software-defined radio receivers, the RTL-SDR with RTL2832U ADC chip offers 25 MHz to 1760 MHz bandwidth and a 0.5 PPM TCXO (customization is available). This hardware's mobility and simplicity of using it are the most appealing feature. Hardware components are required in the SDR technology, the description of the paradigm itself highlights the need for supporting specialized software. This section provides a description of the key software tools that allow SDR signal modification [16]. The Software Radio Tools include among other

- National Instruments - LabVIEW (1986 - present)
- US Military - Speakeasy I (1992-1995)
- Vanu Software Radio (2001- present)
- GNUradio (2001 - present)
- Flex-Radio SDR-1000 (2002-present)
- Tsao, SDR Framework (2002)
- Agile Radio (2003)

- Call Radio (2005 - present)
- Rice - WARP (2006 - present)
- High Performance SDR (2006 - present)
- Virginia Tech - Open Source SCA Implementation (2006 - present)
- Lyrtech - Small Form Factor SDR (2007 - present)
- Virginia Tech - Cognitive Engine (2007 - present)
- HYDRA (2007)
- P-HAL (2008 - present)
- Microsoft - SORA (2009 - present)
- MATLAB/Simulink/USRP (2009)

This list is not complete, but it shows the increasing popularity of the SDR technology [17].

The aim of 3G software radio is to execute all symbol and chip rate processing in software. So, in the section 4.1 begins with an examination of the necessary signal processing power for UMTS (Universal Mobile Telecommunications System) and then presents the key CDMA (Code Division Multiple Access) layer one processing operations, such as path finding and rake antennas. The architecture specifics of possible computer hardware such as DSPs, FPGAs, RCPs, and ACMs are supplied, as well as an estimate of the number of users those devices can handle. Main focus in this section discussion of symbol and chip-rate partitioning.

DUCs and DDCs execute digital frequency conversion; in terms of software, they represent a step among completely programmed DSPs and fixed-function ASICs. Those are also known as application-specific standard parts. They managed practically between digital baseband processing at the network end and digital conversion (ADC and DAC) at the platform's RF end. Simplest terms, they are two-port digital devices with wideband intermediate frequency signals at one port and narrowband single carrier baseband signals at the other. They are, however, more than simply basic devices that fulfil a predetermined purpose when switched on; they contain microprocessor interfaces and inbuilt microcode processors [18].

Why use DUCs and DDCs?

DSPs and ASSPs were considered in the segmentation of the digital frequency conversion functionality. The FPGA is another option for splitting this functionality. The benefit of meeting that software using this device offers the requirements are more accurately. However, the cost of developing and manufacturing an FPGA is likely to be higher. An FPGA's circuit rate can be 10 times that of a dedicated ASIC, which would result in more resource and board real estate being consumed for the same level of performance. As a result, with DSPs ruled out as too inefficient and FPGAs ruled out as too expensive, DDCs and DUCs are regarded as having the optimum combination of software scalability, performance, and cost for 2G and 3G mobile cellular radio.

Frequency converter fundamentals

The following are the primary criteria for digital frequency down-conversion:

- Filter or isolate a narrow frequency component (often a modulated carrier) from the wideband input and reject the rest of the spectrum.
- Reduce the frequency of an isolated carrier, often from an IF to baseband.
- Reduce the data rate to a multiple of the information rate in integers.
- The following are the primary criteria for digital frequency up-conversion.
- One or more narrowband signal sources (generally modulated carriers) are translated up in frequency, often from baseband to an IF.
- Combine the baseband sources to produce a single wideband output.
- Raising the data rate to a digital intermediate frequency rate.
- The software requirements are fully met while employing a DSP which is primary benefit for it, and complete flexibility is obtained. When contrasted to the approach of employing application-specific devices such as programmable digital frequency up and downconverters, the drawback is that the designer trades off flexibility for greater cost, power, and space consumption.

Results and Discussions

Data analysis

Practical: 1 (SDR Sharp, VB Cable, Gpredictor, WXtoImg)

SDR Sharp

Once the SDR device is in connection with the computer, it begins exploring for applications of the technology that provide particular solutions. The traditional uses of SDR include the notion of a single platform and the capacity to rectify mistakes in real time. Furthermore, discovered additional important uses, including dynamic spectrum positioning, Opportunity Driven Multiple Access (ODMA), spectrum regulation, and cost reduction [17].

The SDR concept is beginning to dominate high-impact sectors of telecommunications. This is true for driver assistance [19], GPS signal reception [20], HF propagation analysis, interpretation of cellular technology emissions [21], notably OFDM (Orthogonal Frequency-Division Multiplexing) modulation [16], and identity of radio frequency emissions [22].

The first program, SDR Sharp, displays in real time all of the measurements that the SDR device is capable of producing. As shown in figure 5, it provides the user with four primary windows. The top one displays the spectrum in real time, with three FM radio stations visible in the selected sample.

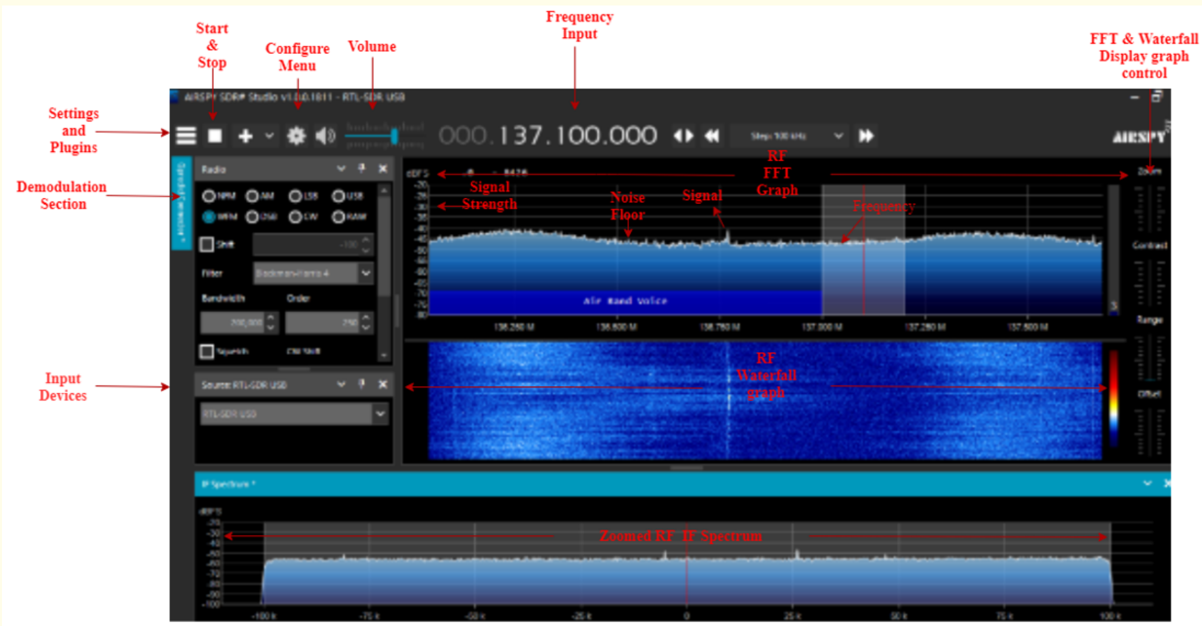
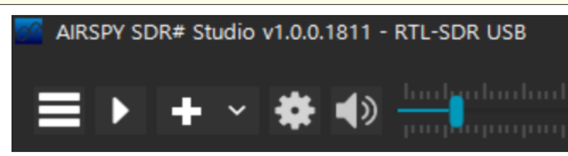
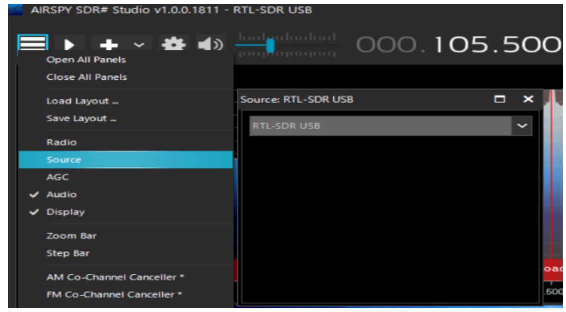
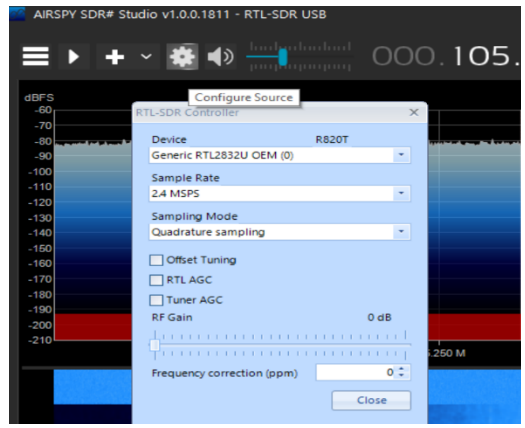
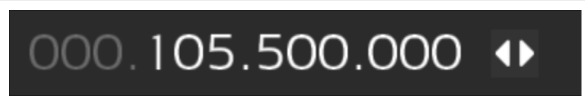
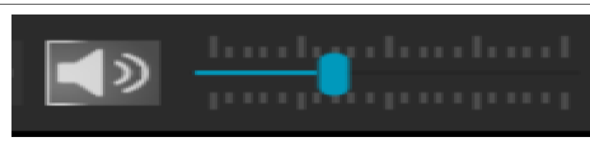
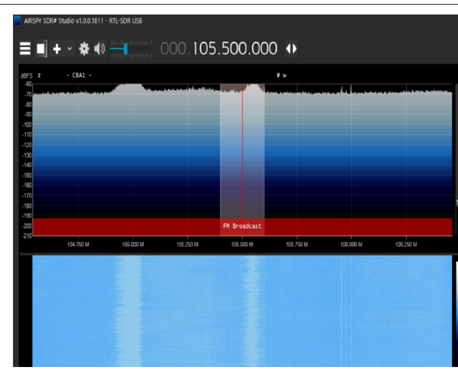
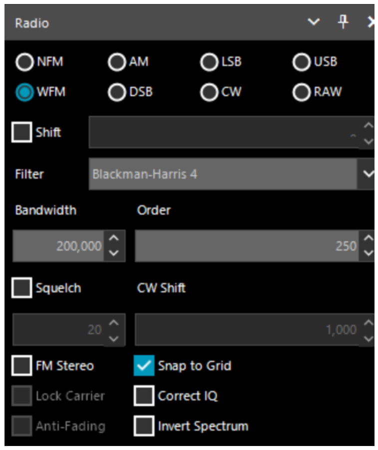
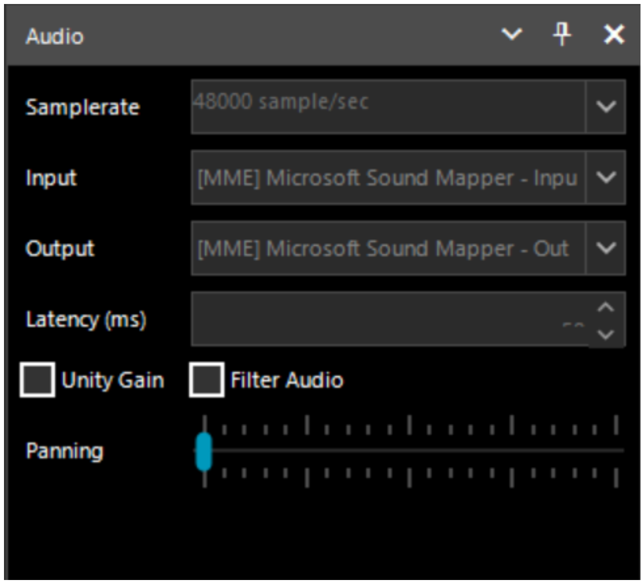
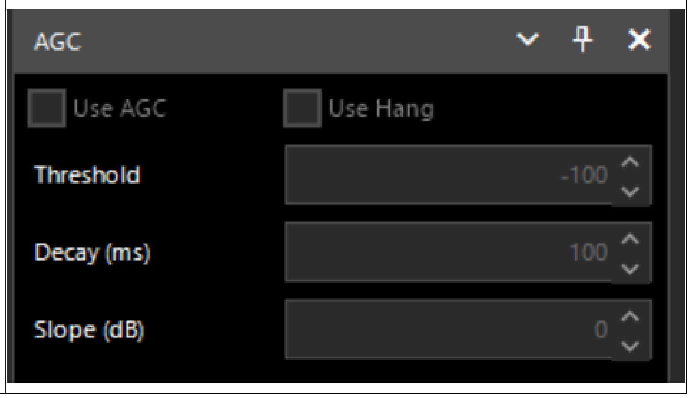


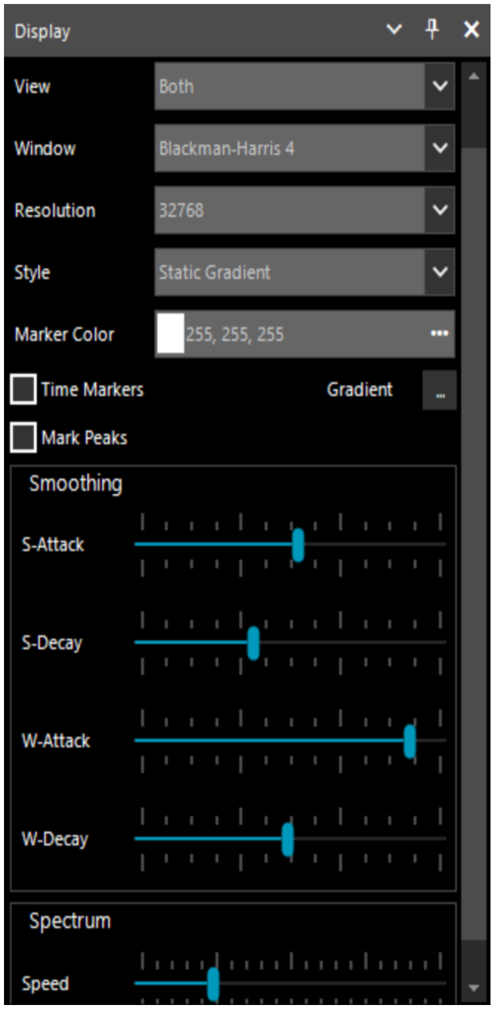
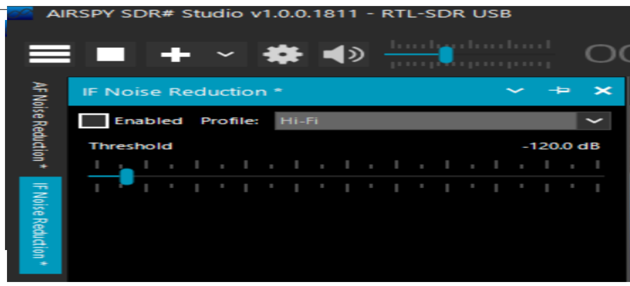
Figure 5: The visualization of spectrum is shown with SDR sharp main window.

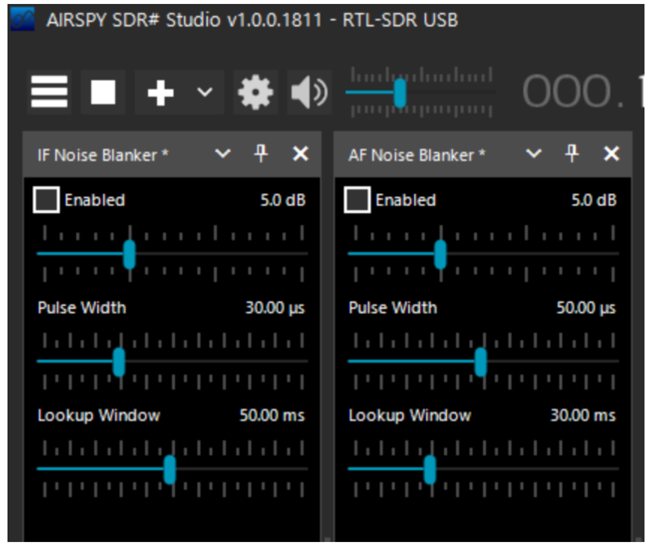
The majority of the options in SDR sharp's windows impact the software digital signal processing (DSP) side of things. These DSP parameters must be adjusted to maximize signal explanation [23]. The features and functions of the SDR sharp has been explained in table 2.

Sr. No.	Control/ Feature's Name	Explanation	Screenshot of Control/Features
1	Play Button/ Stop Button	This button uses for stat and stop the SDR.	

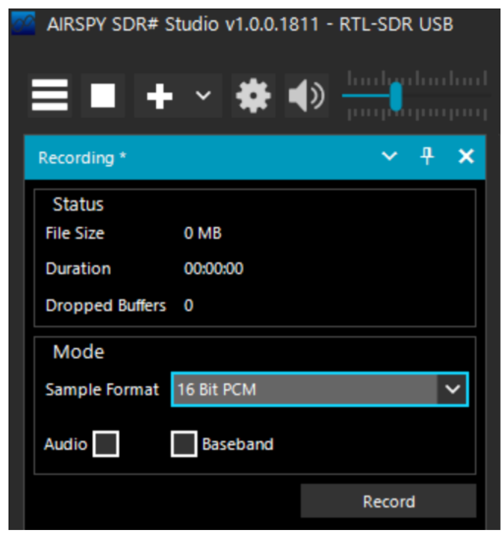
2	Source	This is a drop-down menu for selecting the SDR input device to be used. Select RTL-SDR/USB when using an RTL-SDR. Make sure not to pick RTL-SDR/TCP unless connecting to a remote server using rtl-tcp.	
3	Configure Menu	When you click this (looks like setting button) button, the configure menu appears. In this section, one can modify parameters such as the sampling rate (bandwidth) and RF gain.	
4	Frequency Input	Frequency input divided in to four parts. Each parts containing 3 values (for ex. 000.105.500.000). The first section shows GHz frequency values, second part is MHz and third one is kHz and last part is Hz.	
5	Volume	Set the volume relatively on your output speakers. Here is the output of signal noise in dB (decibel).	
6	RF Spectrum, RF Waterfall, Tuning Bar	RF Spectrum as a graph in actual time visually. Generally, current signal can pick up and down in this graph. RF Waterfall indicates the graph velocity over the years with new records on the top and previous records on the bottom. The tuning bar indicates a vertical purple line, it indicates that RTL-SDR dongle presently tuned to. in this bandwidth have to be set which covers the place of sign that is tuned. Additionally, bandwidth is adjustable through the use of mouse to in reality drag corner of the shaded region in or outer side.	

7	Radio Tab	You can open this tab from the dropdown menu then choose the type of demodulation mode that the signal at your running tuned frequency have to make use of from this menu. NFM - Narrowband Frequency Modulation AM - Amplitude Modulation LSB - Lower Side Band USB - Upper Side Band WFM - Wideband Frequency Modulation DSB - Double Side Band CW - Continues Wave RAW - Raw IQ signal	
8	Audio Tab	This Menu allows you to adjust the setting for audio processing. Sample rate - listening frequency. Input - it specifies input sound card when using SDR sharp with other sound card source. Output - it specifies speakers (listening) frequency. Unity Gain - set default as OFF (unchecked). It means audio gain is 0 dB. Filter Audio - set default as ON, it improves the voice signal through filtering audio. It eliminated excessive DC noise.	
9	AGC (Automatic Gain Control)	Use AGC - By default, it has to be turn OFF. AGC will strive to manage at the Audio level in order that loud sounds are not too loud and low sounds aren't too low. When you need to listen AM/USB/LSB indicators as the strong signal on this time you may turn ON. Use Hang, Threshold (default -100), Decay (default 100), slop (default 0) - Those function allows you to modify AGC behaviour.	

10	FFT Display	FFT display will allow us to adjust the spectrum analyser screen and waterfall. View - set as both so it is showing both screen RF spectrum and Waterfall. If you PC is working slow you can remove the waterfall. Window - set as Blackman-Harris 4, it is a type of windowing algorithm to use on FFT. Resolution - set default as 32768, increasing the value of resolution means increasing quality of signal looks in RF display and waterfall. High resolution can allow you to see much more clear peaks and structure of signal. But beware that high resolution can slow down your PC specially with single core machine. Time Markers - as default we could mark it as OFF. If you would like to ON time markers, then waterfall display shows at what time particular signal was broadcast. Gradient - it allows to manage colours used in waterfall display. Mark Peaks - we could set default as OFF, if you would like to add a circular marker on every single peak on RF spectrum. S- Attack/S-decay - it changes the amount of smoothing and averaging in RF spectrum display. W-Attack/W-Decay - it changes the amount of smoothing and averaging on waterfall display. Speed - it shows the how fast RF spectrum and Waterfall Outputs.	
11	Digital Noise Reduction	AF noise reduction (audio) and IF noise reduction: It is advantageous to activate this function for weak and noisy analog signals. This setting reduces the background noise. IF uses the noise reduction algorithm on the IF signal. The Threshold slider can be used to optimize the strength of the algorithm applied with this profile for the type of audio you are hearing. Profile section - Hi-Fi, Talk, Speech, Narrowband, Custom.	

<table>
<tr>
<td>12</td>
<td>Noise Blanker</td>
<td>It is a type of algorithm; it can be enabled by default. It helps us to reduce impulsive and pulsing like noise from other sources like spark Gaps. It can come from other sources like motor, electricity lines, Power over Ethernet and switching power supplies. This algorithm can simply remove any samples which have large pulses of energy in them. In SDR Sharp two types of Noise Blanker IF noise blanker and AF noise blanker. IF noise blanker remove pulses from the FFT and Waterfall where AF noise blanker only work with current area that is currently demodulated.
Adjust the slider until pulsating noise disappears and try to keep signal active.</td>
<td>
</td>
</tr>
<tr>
<td>13</td>
<td>Recording Tab</td>
<td>This menu allows you to make audio recordings. Allows you to choose the recording quality level. RTLSDR only has 8 bits but we can choose PCM option less than 8 bit, it saves a significant amount of disk space.

Note that if you choose the save option, it may use a lot of disk space. while checking the baseband, you record the I/Q (In-Phase and Quadrature) recording.

If you have received a lot of lost buffers, your PC or disk may not be fast enough to process the recording.</td>
<td>
</td>
</tr>
<tr>
<td>14</td>
<td>Frequency Manager Tab</td>
<td>This menu allows you to save the frequencies of interest in a database. You can also add a new frequency by clicking on NEW.

It would add a frequency with the currently tuned frequency and set it as the bandwidth.

You can also change the name of the frequency in the group for easy management.

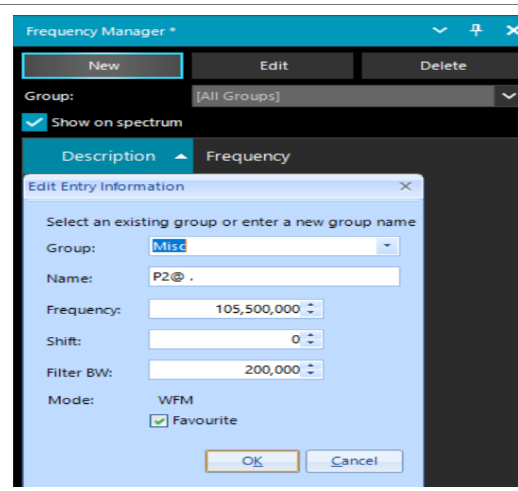
By default, click as display on spectrum, it will be displayed in Spectrum as saved frequency.</td>
<td>
</td>
</tr>
</table>

Table 2: SDR Sharp's characteristics are described in detail below.

Software 2: Gpredictor

GPREDICT is a real-time satellite tracking and orbit prediction tool that uses a mathematical model of the orbit to forecast the position and velocity of a satellite at a given moment. A large number of satellites can be tracked and their positions, and other data can be shown in lists, tables, maps, and polar plots (radar view) [24,25]. Firstly, Gpredict launches the Amateur module. Figure 6 depicts the configuration of this module, which includes three separate views: a map view, a polar view, and a single-sat view. In Gpredict, four distinct perspectives are currently available.

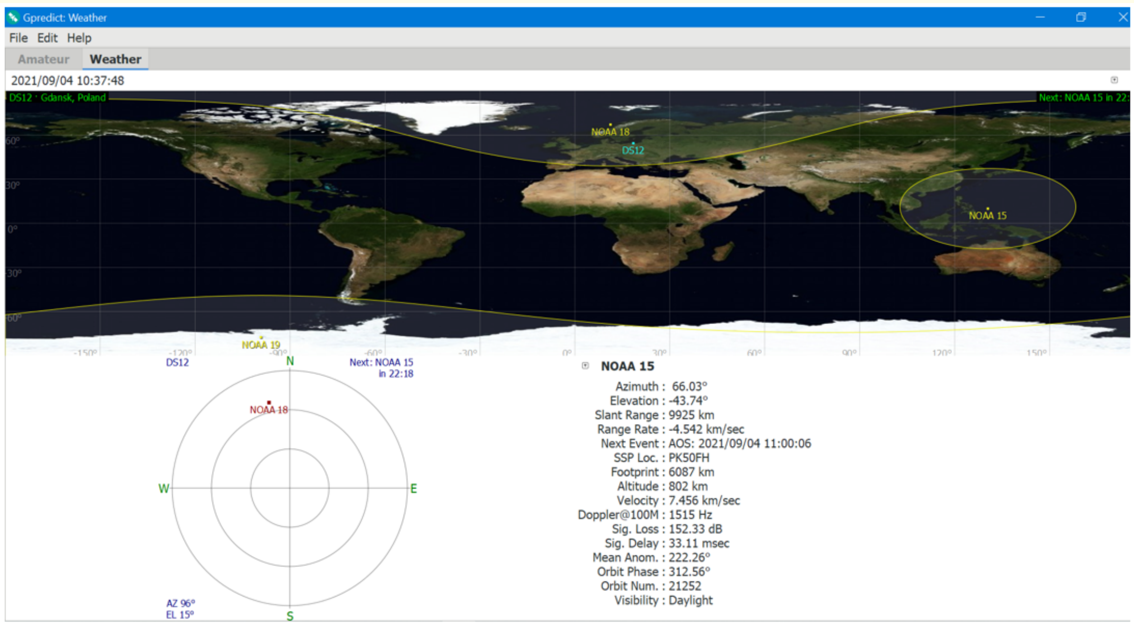


Figure 6: Gpredict main window.

The list views

A list/table view presents the satellite data, with one satellite per row. Information on several satellites at the same time can be presented easily. Each row is dynamically sorted in Realtime according to the sorting criteria (e.g., elevation, next event, etc.).

The map views

Viewing satellites on a rectangular map is possible with Map View, which displays the satellites' footprints (coverage area). With this tool, you will be able to see which satellite is during which location at any moment. For multiple orbits, the map view can also show the satellites ground track on the Earth's surface, if available.

The polar view

Selected satellites within range can be seen in Polar View, or Radar View. Distance and elevation are determined by the polar and radial coordinate axes, respectively. When used to locate a satellite, it gives you a general notion of wherever to "search".

The single satellite views

The Single-Satellite View can provide extensive information about a single satellite in a highly effective manner. Its benefit over the list view is that it is far more efficient, as it only displays one satellite.

Figure 7 shows the different set up view for satellite, for this window follow this path:

Edit → Preferences → modules.

Gpredict features

- Using the NORAD (North American Aerospace Defense Command) SGP4/SDP4 algorithms, fast and precise real-time satellite tracking is possible.

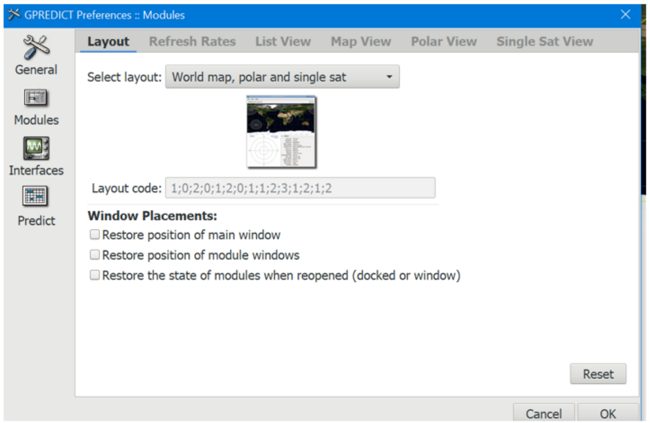


Figure 7: Window for different set up view.

- Satellites and ground stations are not limited by software.
- Maps, tables, and polar plots are used to create an effective visual display of satellite data (radar views).
- This feature allows you to combine satellites into modules, and each module has its own visual layout and customization options. Multiple modules can be used simultaneously, of course.
- Predictions of future satellite passes that are both accurate and comprehensive. The user may fine-tune prediction parameters and circumstances to allow for both broad and highly specialized forecasts.
- By clicking on any satellite, you may rapidly forecast future passes using context sensitive pop-up options.
- Keplerian Elements are automatically updated from the web through HTTP (Hypertext Transfer Protocol), FTP (File Transfer Protocol), or local files.
- Gpredict fits nicely into current computer desktop environments such as Linux, BSD, Windows, and Mac OS X because to its robust architecture and multi-platform development.
- Under the GNU General Public License, you can freely use, modify and redistribute free software.

Working mechanism of gpredict software

Gpredict is a software that tracks satellites in real time and predicts their orbits. A satellite tracking software is a computer program that uses a mathematical model of the orbit to forecast the location and velocity of a satellite at a particular moment. Once the satellite's location and velocity are known, further information may be derived, such as bearing, distance, footprint, and visibility. figure 8 shows the fundamental operation of a satellite tracking software.

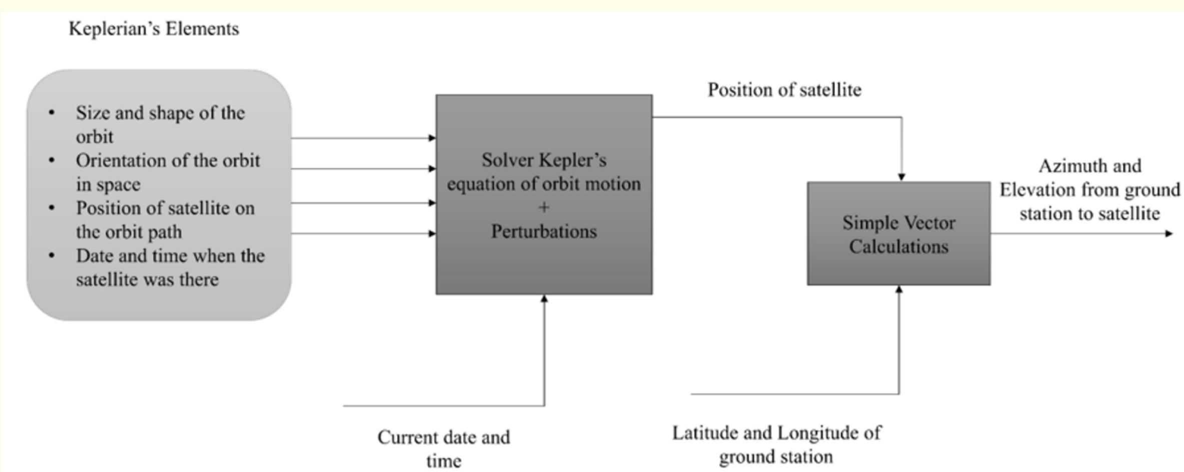


Figure 8: Working layout of GPREDICT software.

There are three types of inputs that Gpredict uses, much like any other satellite tracking program.

- Keplerian Elements defining the satellite orbit, as well as the spacecraft's location and velocity at time t0.
- The day and time when the satellite's location and velocity should be computed.
- The location of the ground station on the planet.

Gpredict radio control and radio configuration

Gpredict radio control

As illustrated in figure 9, the radio control window consists of the following four sections: Satellite, Radio, Target, and Device. Here is a look at each of them in more detail:

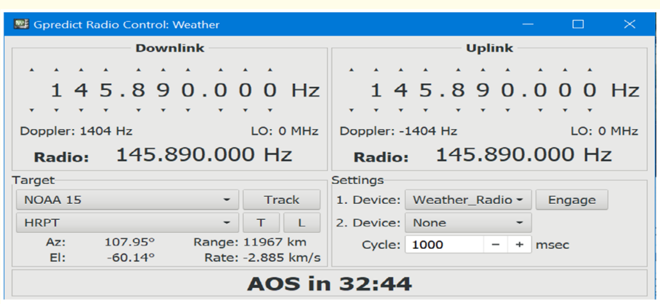


Figure 9: Gpredict radio control window.

Downlink

A frequency from satellite to Earth - in general it is around 17.7-21.2 GHz. The Downlink section contains the satellite downlink frequency's control and status widgets. There is also an indication of the Doppler shift, transverter offset, and corrected frequency (for ex. SAT + Doppler-LO). Only when Track is enabled does the Doppler correction step in (see table 3). This is also the case if the specified gadget is engaged (see table 3). A simple click on an appropriate arrow will allow you to alter your frequency.

Track	Engage	Description
Off	Off	It does not conduct a Doppler correction. The radio is not given any commands. You cannot read the current frequency of any of the radio.
On	Off	In this condition, no orders are sent to the radio and no information is read back about the current frequency of the radio.
On	On	Doppler correction is applied, and the radio is provided frequency setting directives. After reading back the current frequency of radio, active feedback algorithm takes it into consideration.
Off	On	Despite the fact that no Doppler correction is done, frequency instructions are transmitted to radios, and the current frequency is received back from the radio. Using this mode, you may manually operate a remote radio.

Table 3: Operating mode of radio controller.

Uplink

A frequency from Earth to satellite - in general it is around 27.5-31.5GHz. The Uplink section displays the satellite uplink's control and status widgets. It shares the same characteristics as the Downlink area. Even if you are using a receive-only radio, the status widgets are updated. This is extremely helpful if you are utilizing radios where the frequency cannot be changed through CAT when in TX mode. This is the situation with the FT-817; if you want to utilize one, set it as RX only. Gpredict will therefore just adjust the downlink while displaying the corrected uplink so that you may apply the correction manually when broadcasting.

Target

To choose the target object, use the widgets in the Target area. You may change the target at any moment, and any changes it makes to the radio settings will take effect immediately afterward. Doppler shift is only applied to the operating frequency if you enable Track. When you press the Tune button T, Gpredict will tune to the centre of the passband for the specified transponder. Uplink and downlink may be locked by pressing Lock Button L. However, this only works for transponders with passbands, i.e., beacons and single-channel transponders.

Settings

Widgets in the Settings area allow you to choose which radio devices you want to use from the ones you have already specified. A connection in between controller and hamlib driver may be toggled by using the Engage button. Only after the radio device is activated may commands be transmitted to it. In any controller, you may utilize up to two devices. The principal device is the Device 1, which will be utilized for both downlink and uplink depending on the device type (and the option in the 2. Device). As the secondary device, the Device 2. Device only lists radios that are not RX-only. Hamlib communication code operates in its own thread and is periodically triggered. 'Cycle' is a parameter that specifies the time interval between two cycles. According to most experts, one second should suffice. Observe that if the controller algorithm finds five consecutive failures in the communication with hamlib, the device will be automatically disconnected from the network. An AOS/LOS (Acquisition of Signal or Satellite/Line of Sight) timer can be seen at bottom of window, which counts down how much time is left until the next AOS, or LOS event occurs in the future. HH:MM: SS is the format.

Radio configuration

It is easy to configure a radio device, as shown in figure 10. The four necessary fields are listed below.

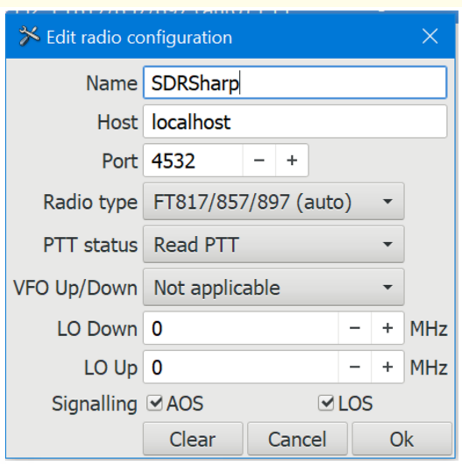


Figure 10: Radio configuration window.

Name

A one-of-a-kind name for the setup. You can use alphabets, underscores, and minus signs, as well as underscores and minus signs.

Host

The computer's host name or IP address to which your radio is linked. If you are on the same computer as Gpredict, you may enter localhost.

Port

Where the rightly server listens on the Internet. It uses the port number 4532 by default.

Radio type

Type of this radio give below.

RX only

Use of the radio should be limited to receiving. For radios that do not offer a TX frequency adjustment via the CAT interface, this can be very beneficial (e.g., Yaesu FT-817).

TX only

Use of the radio should be limited to transmitting only. You can use this option only if you have a separate uplink radio.

Simplex TRX

One at a time, it is best to utilize the radio for receiving and transmission. For transceivers that can function in split mode and where the frequency can be changed through CAT regardless of whether you are in RX or TX mode, this is a helpful alternative. In order for this option to operate, Gpredict must be capable of reading the PTT status through the CAT protocol.

Duplex TRX

In this case, the radio is either an IC-910H or an 847-series full-duplex radio.

PTT status

However, Gpredict will read the status of the PTT and respond appropriately, meaning that RX tuning will only be done if the PTT is turned off, and TX tuning will only be done if the PTT is turned on. Regardless of whether the radio is RX only, TX only or Simplex TRX, it is a critical decision if you want to utilize the same radio for RX and TX.

VFO up/down

There is a VFO (Variable Frequency Oscillator) you need to instruct Gpredict to utilize for uplink and downlink on full-duplex capable radios like the IC-910H or FT-847 when using Gpredict. Each radio has a different setting for this, so check your radio's handbook for the proper one. The radio must be in full-duplex mode before Gpredict can control it. When using full-duplex radios, this option has no influence whether the radio is a simplex transceiver or a transmitter.

LO Down and Up

Using a transverter, these settings allow you to select an offset/local oscillator frequency. The LO Down frequency, for example, is calculated by subtracting the downlink transverter's frequency from the receiver's frequency, in this case 28-30 MHz LO Up is the same.

GPREDICT software different than other software

Gpredict stand out from other tracking applications that it provides for a modular visualization system. Every single one of these modules may be customized independently of the others, allowing you complete control over how the modules appear and feel in terms of design and aesthetics. It is only natural that Gpredict allows you to monitor satellites relative to multiple observer locations - all at the same time [26].

Addition of features in gpredict for future

- Space Mechanics Laboratory.
- Ionospheric trajectories
- An obstruction in the observer's line-of-sight
- Using voice announcements.
- When will two observers be able to communicate?

Software 3: WXtoImg

As a completely automated weather satellite decoder, WXtoImg uses APT (Automatic Picture Transmission) and WEFAX to decode the data. WXtoImg handle both APT broadcasts from geostationary satellites as well as WEFAX transmissions from polar orbiting satellites with WXtoImg software. But it can also export raw pictures to be further processed. JPEG, PNG, BMP, PBM (PGM/PPM/PNM), and AVI formats are available for output [27].

Scanner receivers, for example, have an IF bandwidth too small for WXtoImg to create decent pictures, but there are restrictions to what can be done. APT pictures from NOAA (National Oceanic and Atmospheric Administration) are calibrated using telemetry data from WXtoImg, which also makes corrections for gain variations across the pass. We also calibrate the devices using telemetry data so that we can offer highly precise temperature readings. There are nonlinearities in signal intensity on the GOES satellites that are corrected by using grayscale, as well as normalizing the picture. Temperature calibration is also conducted on IR pictures. To change the gain on other satellites, grayscale and black-and-white bars are utilized instead.

On most versions of Windows, Linux, and Mac OS X, the program enables recording, decoding, editing, and viewing. For many weather satellite receivers, communications receivers, and scanners, WXtoImg supports real-time decoding, map overlays, advanced color enhancements, 3-D images, animations, multi-pass images, projection transformation (e.g., Mercator), text overlays, automated web page creation, temperature display, GPS interfacing, wide-area composite image creation, and computer control. WXtoImg takes advantage of soundcard's 16-bit sampling capability to deliver better decoding than costly purpose-built hardware decoders. Figure 11 shows the main screen of WXtoImg software.

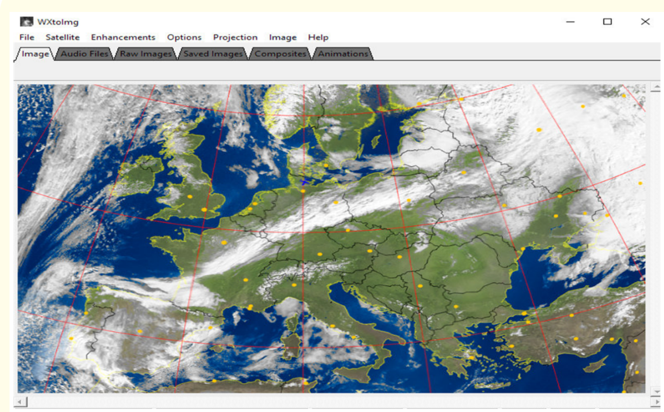


Figure 11: screenshot of main screen of WXtoImg software.

Features of wxtoimg

- Images are converted to common map projections.
- Overlay maps with customizable color palettes and feature sets.
- Temperature displayed in the cursor.
- IR Calibration of temperature and sea surface temperature.
- For embedded applications, use the command line.
- Color pictures that are stunning both during the day and at night.
- Image data from satellites is shown in real time.
- Recording, decoding, and web page creation/publishing are all completely automated.
- Allows for a broad variety of improvements.

Addition of features in gpredict for future

- Multiple polar satellite passes can be combined to generate composite pictures that cover a large area.

- Picture rotation as well as color shifting and grayscale conversion.
- Usage of a GPS to automatically establish the latitude and longitude.
- Display of local time (rather than UTC time).
- In APT pictures, the latitude and longitude under the cursor are displayed, together with the distance (and direction) from the ground station.
- Resample methods (for geographic modification), more noise filter choices, additional contrast settings, and more.

Practical: 2 (orbiton, DDE tracking, SDR sharp)

software 1: Orbitron

Setup of Orbitron satellite tracking program for map selection, TLE (Two-line Elements) or Kepler update, and position. Screenshot of an introduction to satellite tracking and listening Orbitron. Orbitron is a satellite tracking device designed for radio amateurs and astronomers. It is also employed. You may also obtain NOAA satellites, which are less expensive but have a lesser resolution [28].

There should not be too much difficulty getting the needed information passed out now that the program for using the DDE (Dynamic Data Exchange) communication mechanism is operating well, method for a start In order to activate tracking software, satellite tracker Orbitron connect must be started. Using the Auto update TLE option, click OK to allow it update all of the orbital element files. Follow these instructions to set up Orbitron. choose an area to visit System for tracking satellite orbits, Orbitron.

To start tracking satellites using Orbitron with DDE, which launches the satellite tracker with the command SDR. Enter one second in the refresh interval drop down box in Orbitron panel's lower right corner and make settings for the SDR, as shown in figure 12. The features of this software are described in table 4.

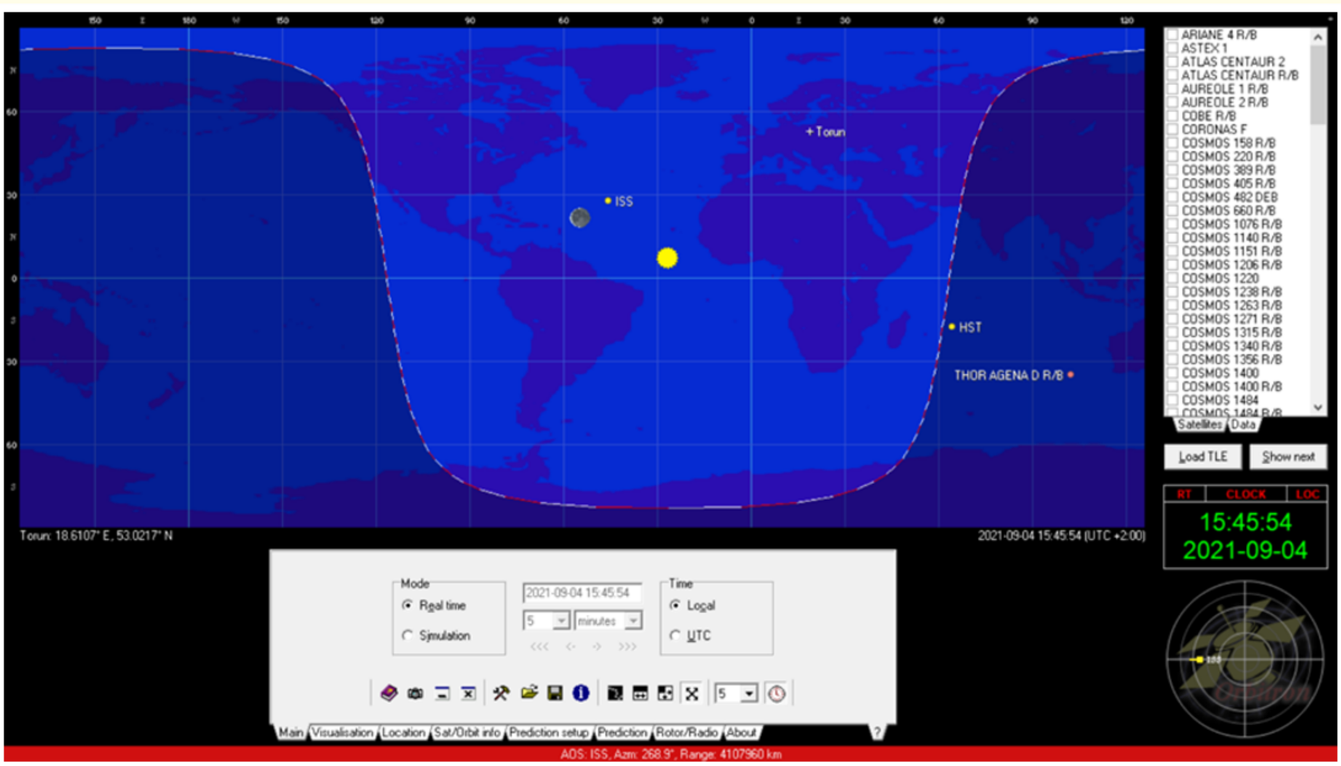
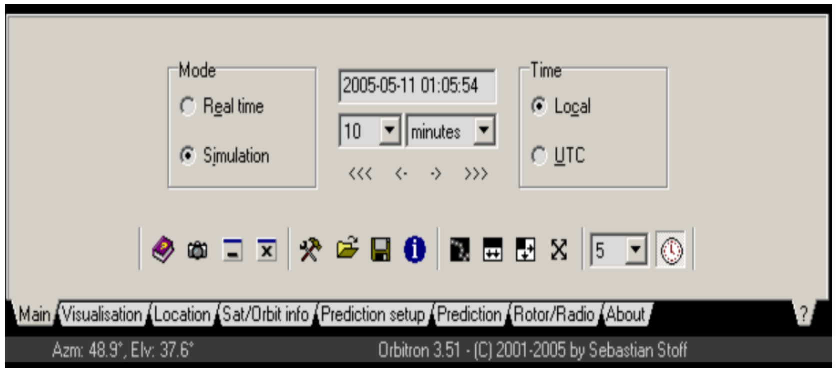
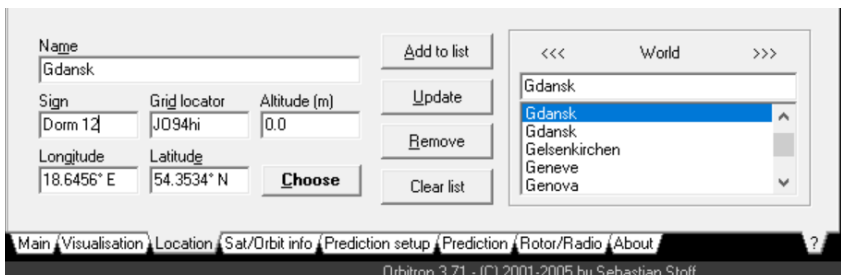
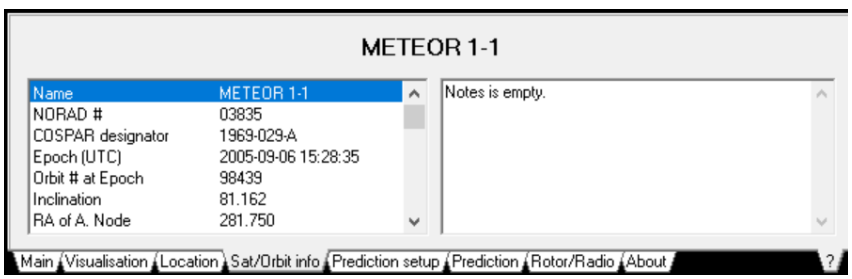


Figure 12: An overview of Orbitron software shown with main task menu.

Sr. No.	Control/Feature's Name	Explanation	Screenshot of Control/Features
1	Main	From this window gives us an option about satellite position which mode you want real time or simulated.	
2	Visualization	From this window you can choose the feature that you want to see on main screen window.	
3	Location	Location option at bottom allows you to set your home address. For those who aren't sure of their longitude and latitude, you can choose a city on the right.	
4	Orbit Info	Where we can choose the different type of satellite, whatever you want to track.	

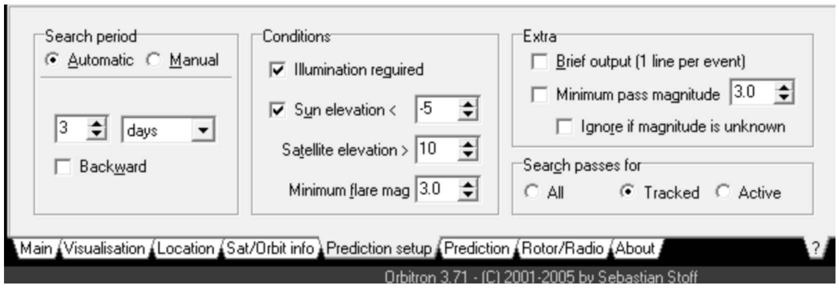
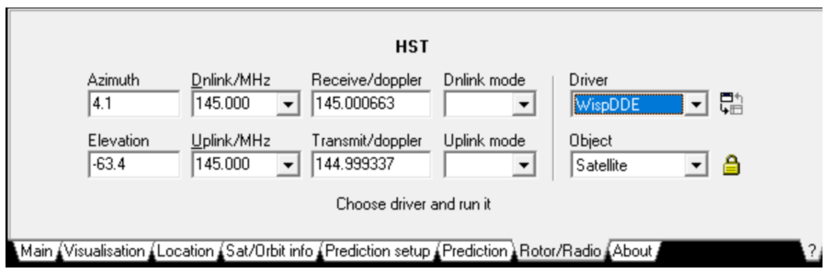
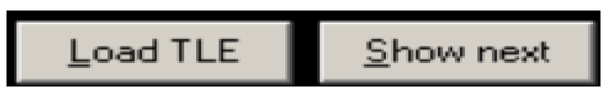
5	Prediction setup	Where we can set up an automatic period and also can choose the different conditions. We also can search passes for All type satellite or tracked or Active based on requirement.	
6	Radio/Rotor	Azimuth: It is an angular measurement in spherical coordinate system. Elevation: Angular distance from object Dnlink: To Transmit data from satellite to Earth Uplink: To transmit data from Earth to satellite	
7	Load LTE	Load the noaa.txt file, or the file for any other satellite you choose to follow, by clicking Load TLE.	

Table 4: Features of Orbiton software explained.

Features of orbitron

- Weather specialists, satellite communication users, astronomers, UFO enthusiasts, and astrologers may all benefit from the application.
- The software displays satellite locations at any time (in real or simulated time).
- Orbitron 3.71 is available in 35 different languages and has its own screensaver.
- You may use the application to get TLE from the Internet. These files provide continually updated information about the orbit of a certain satellite or group of satellites.
- You may track the location of each satellite by using a World Map or a Radar View.
- You may change the view to include or exclude the Sun, Moon, Moon phases, Tails, Compass, and so on.
- Information about each satellite may be viewed, such as its name, NORAD number, COSPAR (Committee on Space Research) designation, Epoch (UTC and Orbit Number), and inclination, among other things.
- You can also estimate where each satellite will be at any given moment.

Addition of features in orbitron for future

- N number of satellites can be loaded from TLE.
- N number of satellites can be tracked at the same time.
- Update database of satellite frequencies automatically.
- Many more translation language needs to update.

Software - 2: DDE tracking (Add-ons)

DDE Tracker - takes satellite position information from Orbitron, WXtrack, or SatPC32 applications and corrects the receiving frequency. When a certain satellite emerges over the horizon, the plug-in scheduler can conduct a set of user-defined actions. The number of commands accessible, shown in figure 13, is dependent on the plugins loaded and will grow over time. You can currently change the type of modulation, set the frequency, bandwidth of the received signal, control the squelch, enable tracking of the satellite frequency, transmit the satellite frequency to other plugins (QPSK - Quadrature Phase Shift Keying), enable other plugins (QPSK, IF recorder, baseband recorder), and run external programs for signal processing using the scheduler.

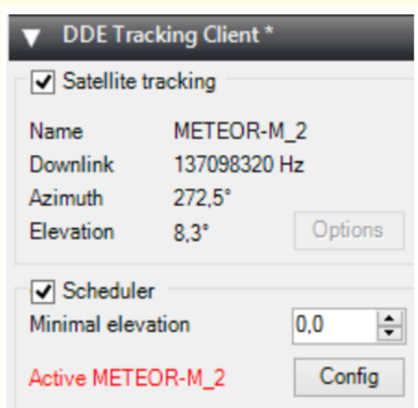


Figure 13: Menu of DDE Tracking is shown with satellite tracking and scheduler option.

There are two ways to use this plugin. The first way is to use it to execute instructions from a satellite window when it is raised over the value defined in Minimal elevation. This collection of commands will be executed when the satellite descends below this height. As a result of the radio tracking frequency command, it is possible to activate or stop the tracking of a tuner's tuning frequency. It is possible to activate or prevent communication of satellite tracking frequency to other plugins using the send tracking frequency command.

DDE (Dynamic Data Exchange) specifications for Nova satellites. In Nova for Windows, DDE servers are supported. A conventional DDE client application may receive satellite tracking and range-rate data from the program. This data might then be used to create customized interfaces for antenna tracking or radio tuning. As implemented in NFW, the following is a broad specification for the DDE protocol. It is important to note that all names and strings are case sensitive.

DDE Server Name: NTW_SERVER

DDE Conversation: NFW_DATA

As soon as the server receives 'TUNE ON', DDE starts in. Even if Auto-tracking isn't active, NFW must display the Auto-tracking Status Box in order to function. We can see the status box if you pick any interface from the Setup/Antenna Rotator menu item. When DDE is enabled, a single string includes the required data is "broadcast" through DDE 2-10 times per second (based on CPU speed and loading):

Sat Name, AZ: Azimuth, EL: Elevation, Range - Rate AH: x

Where, Sat Name: Maximum of 12 characters for the current auto-tracking satellite name as obtained from the NFW database.

Azimuth: Current satellite azimuth, with an accuracy of 0.1 degree and no sign.

Elevation: Current satellite elevation, signed, 0.1-degree precision.

Range-Rate: In this case, Range-Rate is a signed floating-point integer in units of 1/light speed.

AH: Indicates whether the satellite is above the horizon or below it, respectively. Y and N are the two possible values. In this case, the Auto-Tracking Observer's Horizon table is being referenced. Look under Main Menu → Auto-Tracing/Auto-Tracking Observer to find a way to fill up this table. For those who do not fill out the "horizon table" we will presume that the horizon will be 0 degrees wide.

Each field is separated by a single space; there is no space following the (:) label. Neither field lengths nor total string size should be assumed. NFW Auto-Tracking Observer time and date values are referenced to. Using a DDE client, Nova for Windows auto-tracking may be managed. Using the "Poke-Data" command in Delphi to force the DDE string on Nova has the following effects:

- TURN ON: Turn DDE output ON
- TURN OFF: Turn DDE output OFF
- TRACK ON: Turn Auto-tracking ON
- TRACK OFF: Turn Auto-tracking OFF
- SAT: Sets the auto-tracking satellite - The desired satellite catalog number
- ANTAZ: Inform NOVA current satellite AZ
- ANTEL: Inform NOVA current satellite EL

Comparison between used software

In table 5, the features of software (SDRSharp and Orbitron) are compared while receiving the satellite images with applying chosen software. The following features are compared: Computation, throughput, power efficiency, programmability, cost, input/output, data rate, flexibility, portability, modularity, TLE update, sun and moon visibility, add on availability, and CPU configuration.

No.	Feature's Name	Software 1 - SDR Sharp	Software 2 - Orbitron
1	Computation	Fixed Mathematical logic	Configurable Logic
2	Throughput	Low	High Parallel
3	Power Efficiency	Low	High
4	Programmability	Easy	Moderate
5	Cost	Low	High
6	Input/output	Dedicated Ports	Configurable Ports
7	Data Rate	Low	High
8	Flexibility	Yes	Yes
9	Portability	Yes	No
10	Modularity	No	Yes
11	TLE Update	Manually	Automatic
12	Sun and Moon Visibility	No	Yes
13	Add On Availability	More	Less
14	CPU configuration	Less (1 - 3%)	More (4 - 9%)

Table 5: The comparison between two software products (SDR Sharp and Orbitron).

Results from NOAA 15 and NOAA 19

For this portion of the investigation, the SDR Sharp program is utilized. The receiving equipment is linked in the same way that the transmitting hardware is. The hardware and the equipment must be connected. the site where the image will be encoded and processed Obviously, the receiving antenna must also be properly mounted and attached to the hardware of the SDR receiver. Images from NOAA satellites are captured and decoded using system components.

The SDR Sharp program is utilized to obtain images of the NOAA weather satellites, with the exception that for each of the NOAA satellites, the satellite-ground communication parameters are set to processing have to and decode this signal to finally get a satellite weather picture. The WXtoImg software is used to aggregate the images from the satellites, which gives opportunity to perform decoding and real-time view from the satellites.

The ideal configuration is possible to obtain signal of satellite by enabling the SDR Sharp setup. The source of the signal is specified by SDR Sharp setup, i.e., the receiver type, such as RTL-SDR dongle and others. The main aim of this hardware is to capture an accurate input signal.

Two mechanisms are very important while the point comes for proper functionality of Audio panel, which are input and output mechanisms. The employed receiver and the audio input would be the same. In order for the Audio panel to function properly, the input and output mechanisms must be established; in this example, the audio input will be the same as receiver hardware utilized (SDR).

The audio output of the equipment must be return to it, i.e., the emerged sound from SDR Sharp transforms to input source in the WXtoImg decoding program. The output type is then selected in such a situation. There are two possibilities for such a case that audio input port of the equipment is connected with a real cable associated with the audio output port, or the behavior of software as a "virtual cable". Another possibility is to use the computer's sound card, which might arise as disturbing flow of audio data.

The process of tracking the satellite operation frequency and capturing the images from satellites are sometimes critical to find out. SDR sharp software allows to manipulate frequency either manually or automatically with used of plugin. The two satellites are currently available in the orbital of the Earth, which are NOAA 15 at frequency of 137.500.000 Hz, and NOAA 19 at frequency of 137.100.000 Hz.

Following the steps, the setup of WXtoImg software is established for monitoring the satellited based on the geographical location. Another software plays important role to start visualization of the current position of satellite to obtain the appropriate image, which is Orbritron software. TLE database updates automatically once a Orbritron software is employed.

Once a satellite appears in the range of the ground station, WXtoImg software receives the data from the antenna and receipt satellite. This software allows to auto record the continuous signals and transforms into the image in real time. Figures 14 to 19 depicts obtained satellite images from NOAA-15 and NOAA-19, where both software (SDR Sharp and WXtoImg) were employed at the same time. The hardware was used to obtain the satellite images at location of Baltic Sea of Northern Poland (Traugutta 115A, Gdansk).

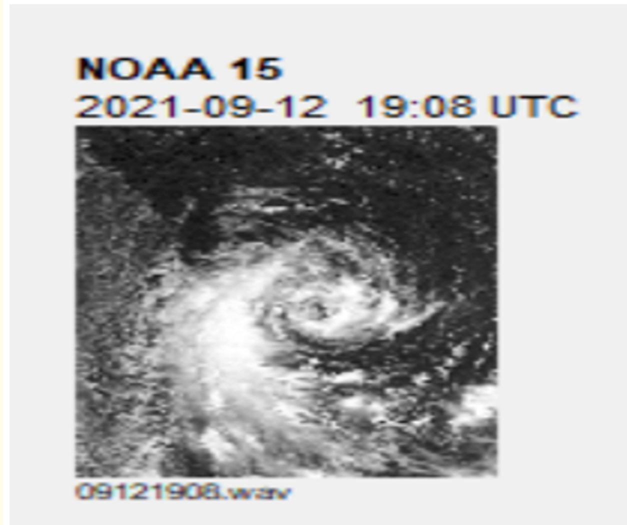


Figure 14: NOAA 15 satellite image captured for weather prediction from WXtoIMG.

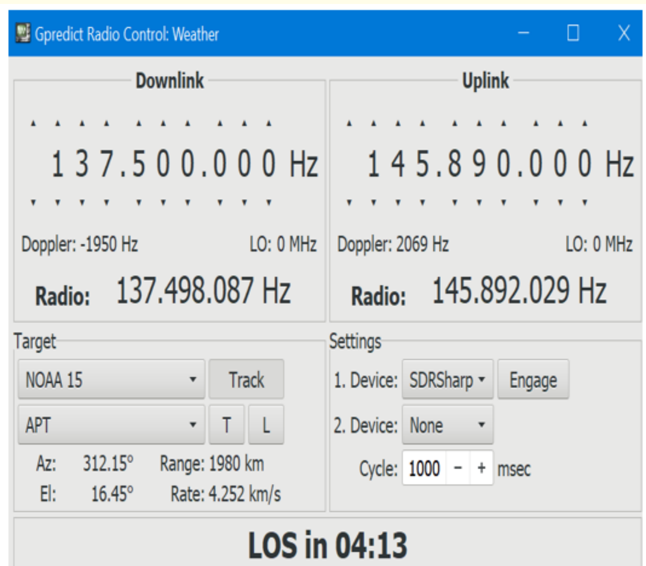


Figure 15: Gpredictor radio control task setup for NOAA 15 with different applied parameters.

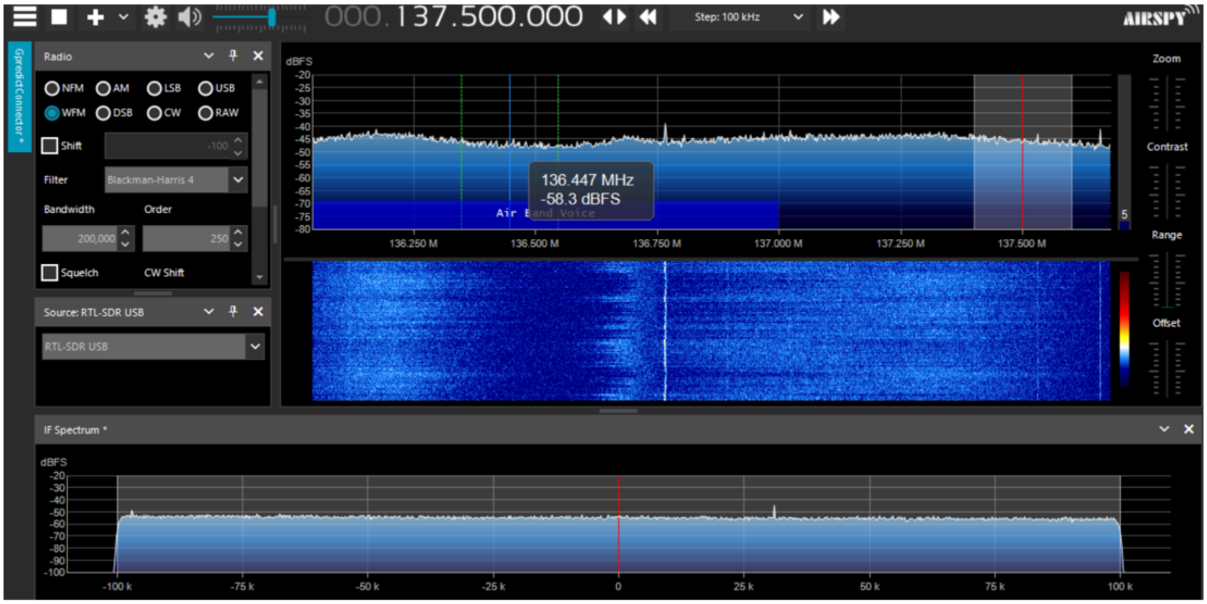


Figure 16: The captured frequency of NOAA 15 from SDRSharp software.

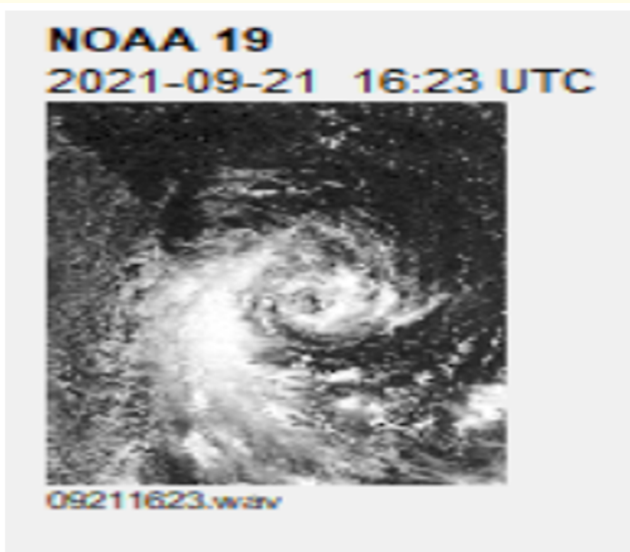


Figure 17: NOAA 19 satellite image captured for weather prediction from WXtoIMG.

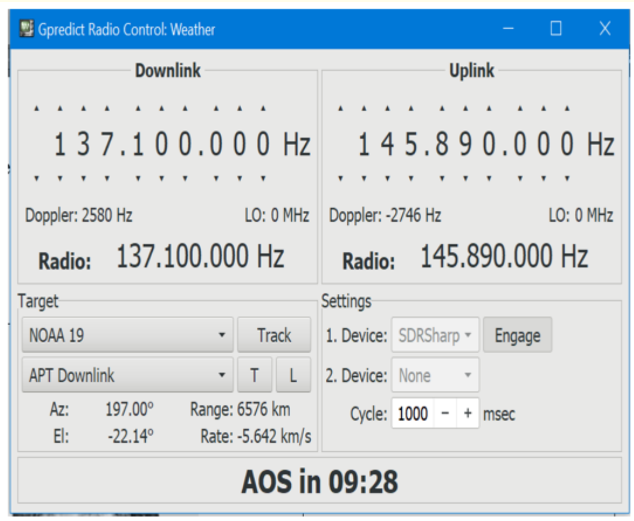


Figure 18: Gpredictor radio control task setup for NOAA 19 with different applied parameters.

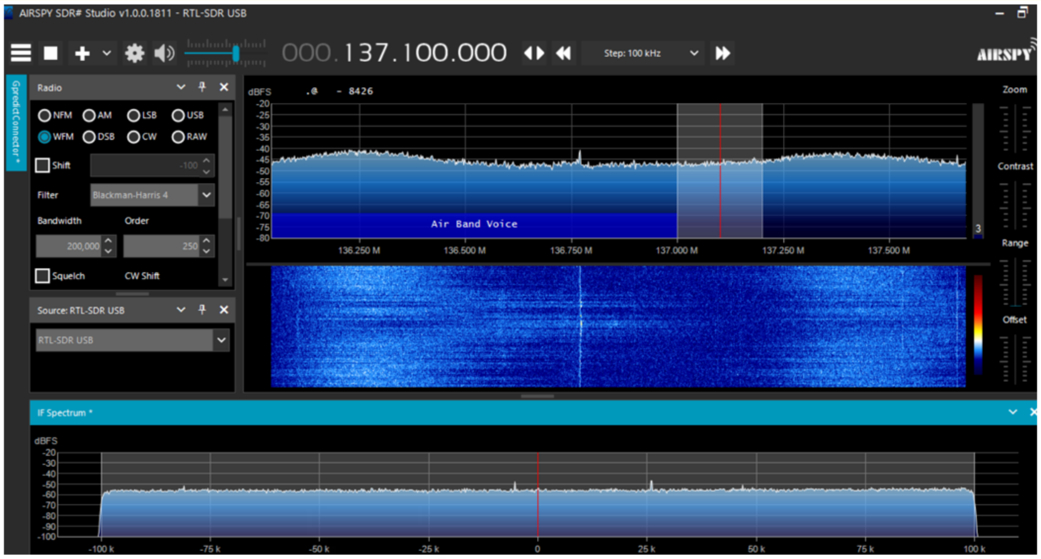


Figure 19: The captured frequency of NOAA 19 from SDR Sharp software.

Conclusion and Future Perspectives

SDR technology has numerous implications in radio environments and is gaining popularity among all types of users. It became obvious that comparing the platforms is a difficult undertaking since not all of them give the information required for an innovative analysis. The RTL2831U Tuner is one of several affordable SDR devices that can be used to manage radio signals using a personal computer. There are many applications of this technology. SDR is a wireless communication technology advancement that can free wireless communication systems from the restriction of standard hardware architectures. It can not only provide new revenue to mobile communication operators, but it can also reduce the cost of network transformation and reduce the project development cycle.

SDR devices, in addition to providing a low-cost radio receiver, can be coupled with open-source software to facilitate frequency band analysis, interference detection, effective frequency distribution assignment, checking repeater operation of the system and assessing electrical characteristics, identifying frequency band intruders, and noise characterization by bands and regions around the world. Nevertheless, based on their cost-benefit analysis, they are able to cut tracking expenses by a significant margin when compared to solutions based on stationary stations now available on the market. The configurability of the analog components of a customizable radio system limits the flexibility of the front-end (antenna, LNA). But the introduction of smart antenna arrays can improve the system's performance since they can adjust their spatial and frequency performance dynamically. Thus, smart antennas would become a vital technology for the development of SDR/SR systems, allowing them to increase their reception/transmission capacities.

Antenna design, signal processing, and software design are required for the creation of SDR/SR systems. Due to a lack of integrated hardware/software design tools, many firms are unable to begin developing their own designs, leaving only a few participants in this sector. There is a need for improved software solutions to be developed in order to ensure reliability. The software packages specified in this work, in conjunction with the hardware parts, allow telemetry decoding to occur. However, only the last stream, in which engineering values of telemetries are deduced from telemetries, is dependent on satellites. As a result, it is important to understand the setup and structure of each telemetry metric.

A more flexible SDR framework, such as GNU radio, will be used in the future because the current approach does not function "as is" for the large majority of satellites in orbit. It is important that the programs that operate on top of SDR/SR systems take into consideration how dynamic the hardware is. To compensate for application and hardware differences, this complicates development. Solution: Create an application environment that can execute all the negotiations and modifications necessary for new apps to run in a dynamic hardware system. SDR technologies have the capacity to make the FCC's secondary use of spectrum programs. The specification of spectrum negotiation procedures and the explanation of liability problems in secondary usage, on the other hand, require additional clarification.

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