

Broadcasting Towers Operation

WEEK 6 – Transmitters and Receivers
with parameters

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Objectives

At the end of the topic students will be able to:

1. Understand the working principle of Transmitters (TX) and Receivers (RX).
 2. Explain Transmitter (TX) and Receiver (RX) parameters.
 3. Understand the monitoring of parameters.
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6.1 TX and RX working principle

- **Signal generation and modulation:** Broadcasting transmitters start with the generation of audio and video signals.
 - These signals are then modulated onto a carrier wave. Modulation can be of various types, either related to the amplitude, the angle or both depending on the broadcasting requirements. The modulated signal carries the information to be transmitted over long distances. Modulation enables multiple signals to be transmitted over the same channel without interference.
 - 5G Cell Search (CS) is the initial step for user equipment (UE) to connect with the 5G node B (gNB) upon powering on. This process uses synchronization signals (SS) broadcasted by the gNB. Unlike 4G, 5G SS may not be centered on the carrier frequency, making their location unknown to the UE.
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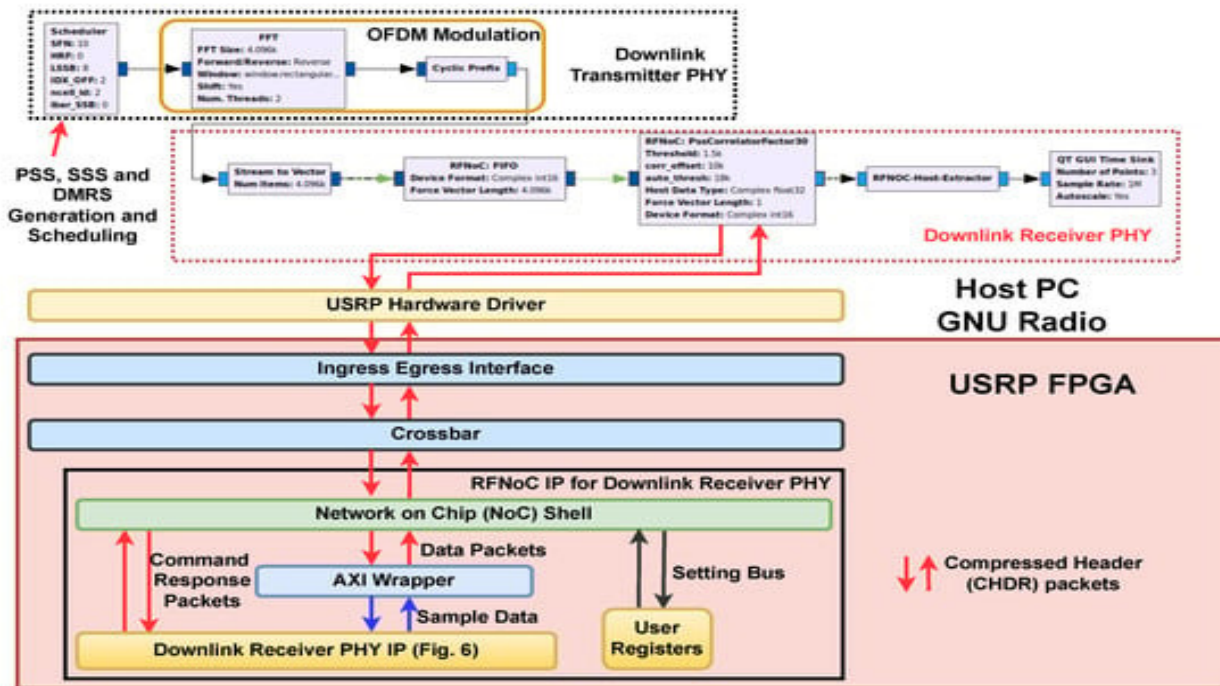
6.1 TX and RX working principle

- A device was developed as mentioned in the article that presents a 3GPP compatible hardware design for the gNB transmitter and UE receiver, featuring a novel down-sampling approach that reduces on-chip memory by 60% and search time by 50%.
 - Performance analysis shows the approach's effectiveness in terms of functional correctness, computational complexity, and latency where the end-to-end 5G CS demonstration using the GNU Radio-based RFNoC framework on the USRP-FPGA platform achieved a 66% faster SS search compared to software that confirmed its commercial viability. (Design and Performance Analysis of Hardware Realization of 3GPP Physical Layer for 5G Cell Search, Khalid Lodhi, Jayant Chhillar, Sumit J. Darak, Divisha Sharma, MDPI, 2023.)
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6.1 TX and RX working principle

- The following figure shows the realization of the proposed device which embeds transmitter and a receiver. (Design and Performance Analysis of Hardware Realization of 3GPP Physical Layer for 5G Cell Search, Khalid Lodhi, Jayant Chhillar, Sumit J. Darak, Divisha Sharma, MDPI, 2023.)

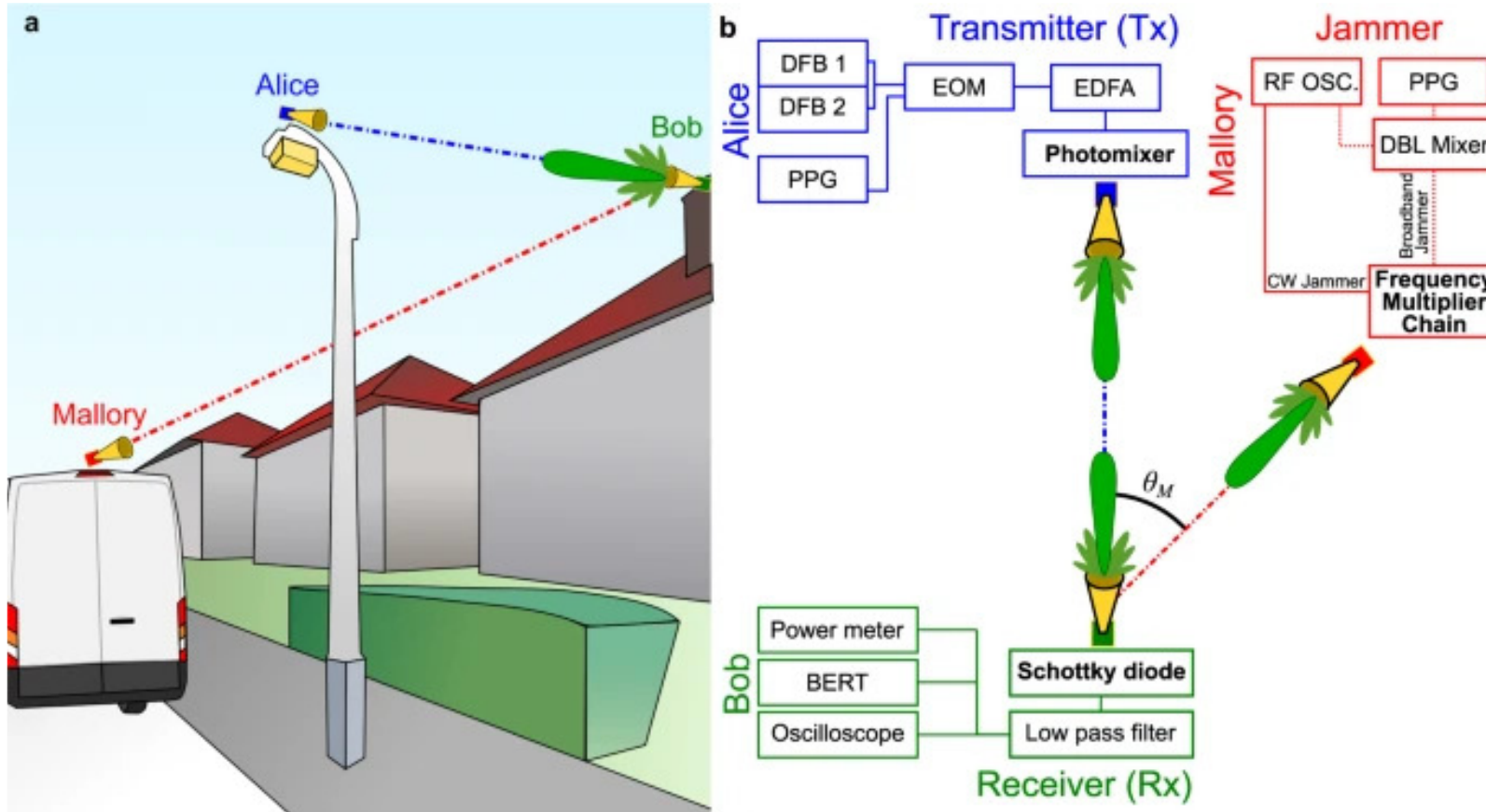
Realization of the CS transmitter and receiver PHY using GNU Radio based RFNoC framework on X310 USRP platform.



6.1 TX and RX working principle

- Another article talking on signal generator is described here: The article discusses a jamming attack where an adversary (Mallory) disrupts a communication link between two parties (Alice and Bob) by targeting Bob's receiver. The experimental setup includes various components such as a bit-error rate tester (BERT), double balanced mixer (DBL Mixer), distributed feedback laser (DFB), electro-optic modulator (EOM), erbium-doped fiber amplifier (EDFA), pulse pattern generator (PPG), and RF oscillator (RF OSC). The study explores the impact of jamming on the communication link and evaluates the effectiveness of different countermeasures. (Jamming a Terahertz Wireless Link, Rabi Shrestha, Hichem Guerboukha, Zhaoji Fang, Edward Knightly, Daniel M.Mittleman, Nature Communications, 2022.)
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6.1 TX and RX working principle



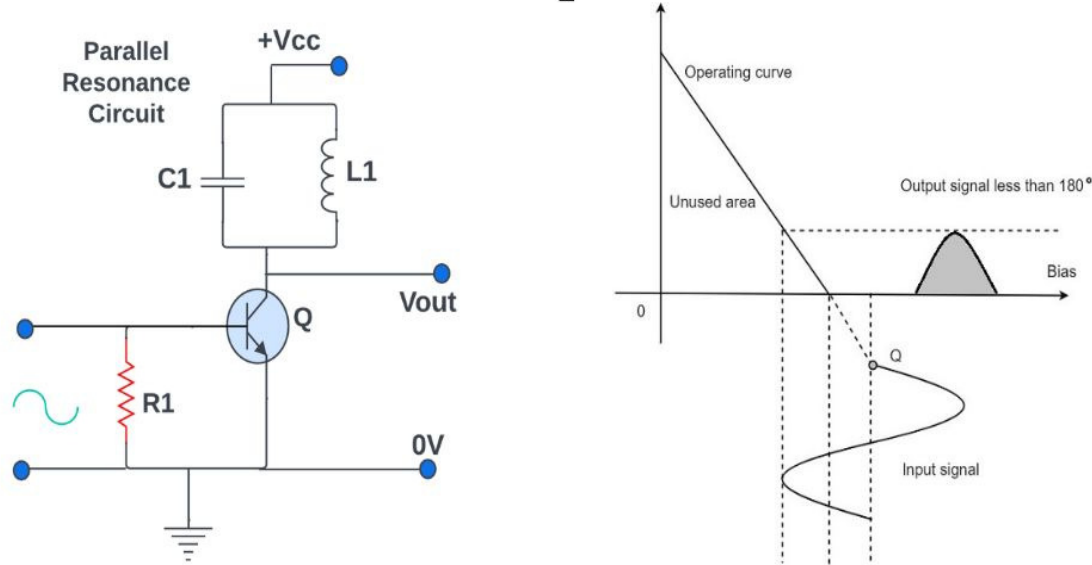
(Jamming a Terahertz Wireless Link, Rabi Shrestha, Hichem Guerboukha, Zhaoji Fang, Edward Knightly, Daniel M. Mittleman, Nature Communications, 2022.)

6.1 TX and RX working principle

- **Amplification:** Once the signal is modulated, it needs to be amplified to ensure it can travel long distances without significant loss of quality and degradation. High-power amplifiers are used to boost the strength of the modulated signal. This step is crucial to maintain the integrity of broadcast over large areas.
 - Due to more Ideal for RF applications and more efficiency than the Class A and B amplifiers, class C is referred. These amplifiers require impedance matching and need efficient cooling for heat management and harmonic filtering to prevent interference.
 - They are ideal for high-power RF applications where efficiency is important, such as cell phones, Wi-Fi devices, and radar systems etc. The design considerations include frequency range, output power, and modulation schemes to optimize their performance in specific RF systems.
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6.1 TX and RX working principle

Class C amplifier

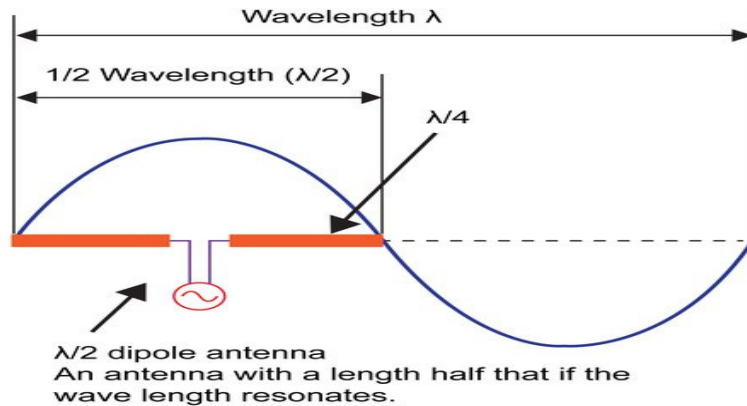


A class C power amplifier is a high-efficiency power amplifier. Where the transistor conducts for less than one half cycle (180°) of the input signal.

(<https://etechsparks.com/fundamentals-of-class-c-power-amplifier/>)

6.1 TX and RX working principle cont'd

- **Transmission:** The amplified signal is then fed into the transmitter's antenna system. The antenna converts the electrical signals into electromagnetic waves, which are radiated into the atmosphere. The design antenna height play a significant role in determining the coverage area of a broadcast.
(Broadcast Engineer's Reference Book, EPJ Tozer, Focal Press, 2004)



(<https://www.quora.com/Does-an-antenna-need-to-be-the-exact-length-as-the-wavelength-of-the-photons-it-emits>)

6.1 TX and RX working principle cont'd

The range of antenna height required to transmit a baseband signal of frequency ranging from 20Hz to 20KHZ (audio signal) is calculated as follows:

$$\lambda = \frac{c}{f} = \frac{3 * 10^8}{20} = 15000Km \text{ For 20Hz, the height of antenna for this signal is;}$$

$$h = \frac{\lambda}{4} = \frac{1500}{4} = 3750Km \text{ And it is really very difficult to build practically.}$$

$$\lambda = \frac{c}{f} = \frac{3 * 10^8}{20000} = 15000m \text{ For 20 KHz, the height of antenna for this signal is;}$$

$$h = \frac{\lambda}{4} = \frac{1500}{4} = 3750m \text{ And it is really very difficult to build practically.}$$

For practical height of antenna; by using modulation and taking a carrier signal in the range of MHz, let us take an example.

$$\lambda = \frac{c}{f} = \frac{3 * 10^8}{100 * 10^6} = 3m \text{ For 100 MHz, the height of antenna for this signal is;}$$

$$h = \frac{\lambda}{4} = \frac{3}{4} = 0.75m = 75cm \text{ And it is really very easy to build practically.}$$

Hand-out for students, batch 2019: Analogue and Digital Communication

6.1 TX and RX working principle cont'd

- **Propagation:** The electromagnetic waves travel through the air at the speed of light. These waves can propagate through various mediums, including the ionosphere, which can reflect the waves back to Earth, allowing for long distance transmission. The propagation characteristics depend on the frequency of the transmitted signal.
 - **Reception:** At the receiving end, antennas capture the electromagnetic waves and convert them back into electrical signals. These signals are then demodulated to extract the original audio and video content. The quality of reception depends on factors such as the signal strength, interference and the quality of the receiving equipment.
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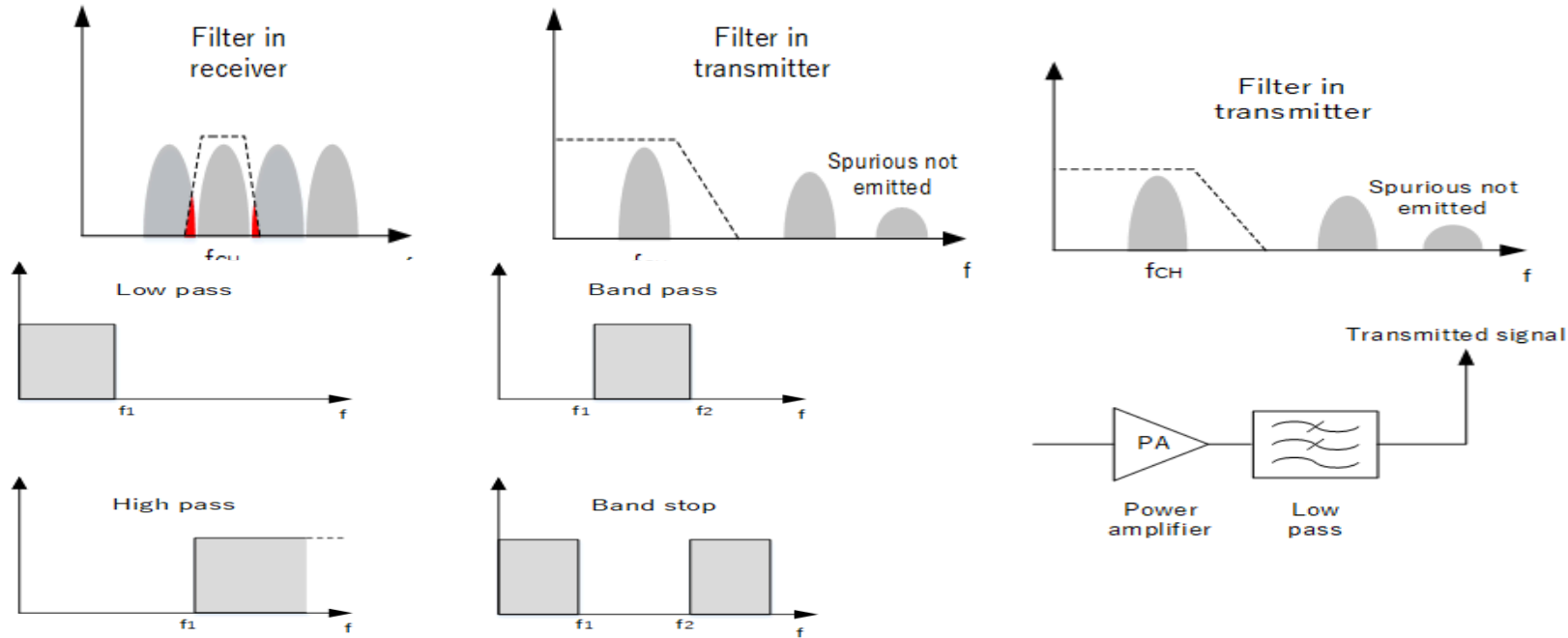
6.1 TX and RX working principle cont'd

- **Signal reception:** The primary function of a receiver in a broadcasting tower is to capture electromagnetic waves transmitted through the air. The receiver's antenna is designed to pick up these waves and convert them back into electrical signals. The efficiency of this process depends on the design and orientation of the antenna, as well as the frequency of the incoming signals.
 - **Tuning and filtering:** Once the signals are captured, the receiver must isolate the desired frequency from all other signals through tuning, where the receiver's tuner selects the specific frequency of interest. Filters are then used to remove any unwanted frequencies, ensuring that only the desired signal is processed further. (Modern Digital and Analog Communication Systems, B.P. Lathi, Zhi Ding, Oxford University Press, 2010.)
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6.1 TX and RX working principle cont'd

- **Amplification:** The filtered signal is often weak and requires amplification to be useful. The signal strength is boosted without significantly adding noise which is crucial for maintaining the clarity and quality of the received signal, especially in areas with weak signal strength.
 - **Demodulation:** The amplified signal is demodulated to extract the original audio or video content by reversing the modulation process performed by transmitter. Techniques are used to accurately retrieve the transmitted information.
 - **Output and processing:** The final step involves converting demodulated signal into a form that can be used by the end device, such as a radio or television. This may involve additional processing to enhance the signal quality, the lastly sent to the output device, where it is converted into sound or images.
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6.1 TX and RX working principle cont'd



(https://www.cdt21.com/design_guide/filters-and-radio-system-design/)

The radio spectrum is a limited resource with many users transmitting in closely spaced channels. Filters ensure reception of the wanted signal and suppress all other signals. They also ensure only in-band frequencies are transmitted to prevent interference to other users in the band or to any other bands.

6.2 TX and RX parameters

Antenna parametric consideration

- Selecting the right antenna is crucial and must be compatible with receiver specifications and meet size, weight, and environmental requirements.
- **Mounting types**; to select the right antenna, first determine the suitable mounting type based on the application requirements, if it will be integrated internally, like in a mobile device, or externally, which often requires protective housing for outdoor use to ensure optimization for its intended environment and application.
- **Frequency and wavelength**; the range of frequencies to operate within should be precise, an antenna quarter wavelength long will provide the best efficiency and deliver the highest signal quality.

(<https://www.2j-antennas.com/services/antenna-specification-explanation>).

6.2 TX and RX parameters

- It is important to note that 4GLTE and 3G/2G antennas have the potential to be used in applications requiring ISM standards. 4GLTE range specification of 698-960MHz and 3G/2G from 824-960MHz, meaning the ISM 868MHz standards operate from 863-870MHz and are located within the 4GLTE and 3G/2G range. The same applies for ISM 915MHz standards that operate within 902-928MHz, or dual band 868/915MHz.
 - **Standards & bands** are important for better quality as well as compatibility in transmission and reception. Antennas are tested and measured to achieve the most reliable performance results.
 - **Testing parameters and methods** vary from manufacturers and should be availed (free space, metal plate, plastic plate, glass, etc.) and known while installing antennas to ensure performance.
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6.2 TX and RX parameters

- **The return loss** is measured in decibels (dB) and represents how much energy is transferred from the device to the antenna. The lower the measurement the better. Using the return loss to identify how the impedance of the antenna performs across the entire spectrum can help to estimate the bandwidth and operating frequencies.
 - **Voltage Standing Wave Ratio (VSWR)** is another parameter used to measure how much energy is transferred from the device to the antenna but with a different mathematical scale than the one used for Return Loss. The lower the measurement the better.
 - **Narrow** band and **wideband** antenna are selected to meet the requirements with the matching bandwidth as narrowband and wideband are not interchangeable. For the bandwidth, short and wide frequency range.
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6.2 TX and RX parameters

- **Antenna efficiency** (radiation efficiency) is a measure of the rate of conversion of the radio frequency power received into radiated power. How much energy is radiated from the antenna to the air or how good is the antenna to radiate the energy.
 - **Antenna gain** is the measurement of an antenna's ability to direct or concentrate radio frequency energy in a particular direction or pattern. This is typically measured in dBi (Decibels relative to an isotropic radiator).
 - **Average gain** is represented with a different mathematical scale (dB) and takes into consideration any mismatch losses.
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6.2 TX and RX parameters

- The **radiation pattern** of an antenna describes the strength of radio waves transmitted in various directions. Omnidirectional antennas provide a 360-degree doughnut-shaped pattern, ideal for connecting devices on the same plane.
- Hemispherical antennas cover half the space, while directional antennas focus their radiation in one direction for longer distances with less interference.
- **Polarization** refers to the orientation of the electric field of an electromagnetic wave, with the two most common types being linear and circular.
- In linear polarization, the electric field vector remains in a single plane, while in circular polarization, the vector rotates in a circular motion, completing a full turn each RF cycle. Circular polarization can be right-hand (RHCP) or left-hand (LHCP).

<https://www.2j-antennas.com/services/antenna-specification-explanation>

6.2 TX and RX parameters

- A **ground plane** is a surface area or metal that acts as a conductor and reflects the radio waves from other antenna components. The shape, size and the required clear area play an important role for radiation characteristics and gain.
- The **maximum input power** in Watts should be transmitted to one antenna port without damaging it while maintaining performance.
- Choosing the right RF **cable and connector** is essential for optimal antenna performance, as the connector links the antenna to the RF system and the cable transmits signals between transmitters and receivers. Cable length affects signal quality and strength, so selecting high-quality, compatible components is crucial. When evaluating a product, consider the connector's gender, polarity, geometry, and the cable length before requesting a quote.

<https://www.2j-antennas.com/services/antenna-specification-explanation>)

6.2 TX and RX parameters

- **Output power** is a critical parameter that determines the range and quality of the signal transmitted. Higher output power typically extends the coverage area but can lead to interference if not properly managed.
 - Different cellular technologies operate on various **frequency bands**. The choice of frequency affects propagation characteristics, interference, and overall network performance. The frequency should be stable to avoid signal drift.
 - The **modulation scheme** affects how information is encoded onto the carrier wave. Common schemes include QPSK and 16-QAM, each offering a trade-off between bandwidth efficiency and signal robustness.
 - **Antenna gain** influences the directional strength of the transmitted signal. Higher gain antennas can focus energy on specific directions, improving coverage in targeted areas.
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6.2 TX and RX parameters

- **Receiver sensitivity** indicates the minimum signal level that can be detected. Improved sensitivity enhances the receiver's ability to pick up weak signals, critical in areas with low coverage .
 - **Dynamic range** refers to the range of signal amplitudes the receiver can process without distortion. A wide dynamic range ensures the receiver can handle both weak and strong signals effectively.
 - **Intermodulation distortion (IMD)** is an important parameter that quantifies the distortion produced by non-linearities in the receiver. High levels of IMD can significantly degrade signal quality and system performance.
 - The **noise figure** is a measure of how much noise the receiver adds to the signal, affecting the overall signal-to-noise ratio. A lower noise figure is desirable for maintaining high-quality communication.
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6.2 TX and RX parameters

- **Environmental conditions** can significantly impact both transmitters and receivers. Factors such as temperature, humidity, and physical obstructions (like buildings or trees) affect signal propagation and quality.
 - **Continuous monitoring** of the parameters is essential for maintaining optimal performance of cellular broadcasting towers. Implementing advanced monitoring systems allows for real-time analysis and proactive maintenance, ensuring consistent service quality.
 - Monitoring the parameters of transmitters and receivers in cellular broadcasting towers is essential for effective communication. Focusing on these parameters, network operators can improve service quality, extend coverage, and enhance user satisfaction.
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6.3 Monitoring of parameters

Parameters checking and status monitoring for a cellular broadcasting tower

- Effective communication in cellular networks relies heavily on the proper functioning of broadcasting towers. Monitoring and checking the parameters of these towers are crucial for maintaining service quality, extending coverage and ensuring user satisfaction.
 - **Signal Strength (RSSI):** Received Signal Strength Indicator (RSSI) measures the power level received by the antenna to ensure that reliable communication conditions are met. Optimal range with values above -70 dBm considered as withing good while below -90 dBm indicate poor signal strength. These values are equivalent to 100 pW or 10^{-10} W and 1 pW or 10^{-12} W respectively.
(Wireless Communications: Principles and Practice, Theodore S. Rappaport, Prentice Hall, 2002.)
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6.3 Monitoring of parameters cont'd

- **Signal Quality (RSRQ):** Reference Signal Received Quality (RSRQ) indicates the quality of the received signal that helps in assessing the overall quality of the connection. Optimal range with values from -19.5 dB (poor) to -3 dB (excellent). (LTE-Advanced: A Smart Step towards 5G, S. K. Sharma, H. S. K. Lakhwani, and S. R. K. Sinha, Springer, 2016.)
 - **Signal Power (RSRP):** Reference Signal Receive Power (RSRP) measures the power of the received reference signal to critically help in determining the coverage area of the tower. Optimal range with values from -44 dBm (excellent) to -140 dBm (poor). (LTE: The UMTS Long Term Evolution, Harri Holma and Antti Toskala, Wiley, 2011.)
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6.3 Monitoring of parameters cont'd

- **Signal-to-Noise Ratio (SNR):** SNR compares the level of the desired signal to the level of background noise to indicate better signal quality and less interference. Optimal range considering higher values as best with typical good values being above 20 dB. (Digital Communications, John G. Proakis and Masoud Salehi, McGraw-Hill, 2007.)
 - **Latency:** The time it takes for a signal to travel from the transmitter to the receiver, low is crucial for real-time applications like voice and video calls with optimum values below 100 ms. (High-Speed Networks: TCP/IP and ATM Design Principles, William Stallings, Prentice Hall, 2002.)
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6.3 Monitoring of parameters cont'd

- **Throughput:** The rate at which data is successfully transmitted over the network, higher indicating better network performance, optimum values are varying per technology, and it is one of the parameters that influences new technology development such as 4G LTE, 5G, 6G, etc, thus, it should be high to indicate the best transmission. (5G: Fundamentals and Regulatory Framework, K. M. S. D. R. K. K. Jayaraman, Wiley, 2020.)

Status monitoring best practices

(<https://www.eutelsat.com/en/blog/remote-tower-monitoring.html>)

- **Regular monitoring:** Conduct regular or frequent checks, ideally in real-time, to promptly identify and address issues. Use appropriate tools to continuously track the key parameters.
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6.3 Monitoring of parameters cont'd

- **Preventive maintenance:** Implement a scheduled preventive maintenance to inspect and service equipment regularly and identify potential issues before they can cause a big problem.
 - **Energy management:** Track or monitor energy consumption to optimize power usage and reduce costs.
 - **Security and access control:** Implement robust security measures to protect the tower from unauthorized access and vandalism by using surveillance cameras, access control systems and alarms.
 - **Environmental monitoring:** Monitor environmental conditions such as temperature, humidity, and weather conditions to ensure that equipment work within appropriate and safe parameters. Extreme temperatures and high humidity can lead to equipment failure.
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6.3 Monitoring of parameters cont'd

- **Remote monitoring:** Use remote monitoring tools and systems to manage and control tower operations from a central location to detect the issues and respond to them quickly without unnecessary physical site visits.

(<https://aggregate.digital/products/solutions/remote-monitoring/tower-monitoring.html>).

- Effective parameters checking and status monitoring are essential for the optimal performance and vital for reliable operation of cellular broadcasting towers. By focusing on key parameters of transmitters, receivers, system performance metrics and environment such as signal strength, quality, power, SNR, latency, and throughput, and implementing best practices in monitoring and maintenance, network operators can ensure high service quality, extended coverage, and improved user satisfaction within uninterrupted communication.
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6.3 Monitoring of parameters cont'd

Physical and visual inspection of broadcasting towers

- **Physical inspection** involves hands-on examination of the broadcasting tower's electronics and IT equipment to ensure they are functioning correctly and safely. A thorough examination of equipment on structural integrity, functionality and compliance with safety standards
 - **Structural integrity** requires checking the tower's structure for any signs of wear, corrosion, or damage. Ensure that all bolts, joints, and supports are secure. Ensure that all electronic and IT equipment is securely mounted, and that mounting hardware is intact
 - **Cabling and connectors** needs to inspect all cables and connectors for signs of wear, fraying, or damage. Ensure that connections are secure and free from corrosion.
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6.3 Monitoring of parameters cont'd

- **Power supply** requires to verify that power supplies are functioning correctly and that backup power systems (like generators or batteries) are operational.
 - **Cooling systems** make sure that fans and air conditioning units, are working properly to prevent overheating of equipment. Inspect air conditioning units or ventilation systems for good functionality and free of obstructions.
 - **Grounding** requires to ensure it is intact and effective in protecting the equipment from electrical surges. Check that all equipment is properly grounded to prevent electrical hazards and ensure the safety of personnel.
 - **Safety equipment** such as fire extinguishers and first aid kits should be inspected to ensure they are accessible and in good condition.
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6.3 Monitoring of parameters cont'd

- **Visual inspection** involves a thorough visual check of the broadcasting tower and its equipment to identify any obvious issues that might affect performance or safety. It focuses on the external appearance and condition of the equipment, aiming to identify any visible signs of malfunction or deterioration.
 - **Antenna alignment** visually check that antennas are properly aligned and free from obstructions that could interfere with signal transmission.
 - **Equipment condition**: look for any visible signs of damage or wear on electronic and IT equipment, such as cracks, rust, or discoloration.
 - **Environmental factors**: observe the surrounding environment for potential hazards like nearby trees or buildings that could affect signal propagation.
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6.3 Monitoring of parameters cont'd

- **Labelling and documentation** to ensure that all equipment is properly labelled and that documentation, such as maintenance logs and inspection records, is up to date for legible identification and safety compliance.
 - **Cleanliness** of equipment and the area around and their freedom from dust, debris, and other contaminants that could affect performance.
 - **Security** measures, such as locks and surveillance cameras in place and functioning to protect the equipment from unauthorized access.
 - Regular physical and visual inspections are crucial for maintaining the reliability and safety of broadcasting towers. By identifying and addressing potential issues early, operators can prevent equipment failures and ensure continuous, high-quality service.
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6.3 Monitoring of parameters cont'd

Summary

- Physical and visual inspections of broadcasting towers and their equipment are essential for maintaining safety and reliability. These evaluations focus on the structural integrity of the towers, checking for corrosion, rust, and environmental damage.
 - Inspectors also examine the materials used, such as steel and concrete, along with the quality of joints and welds. Additionally, the condition of antennas, transmission lines, and grounding systems is assessed to ensure optimal signal quality and protection from hazards.
 - Regular inspections help organizations comply with regulations, reduce downtime and enhance the longevity of their broadcasting infrastructure. (Broadcast Engineering: Technical Analysis and Design, Bob G. Dyer, Focal Press, 2013.)
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Thank you for your good attention
Q&A

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