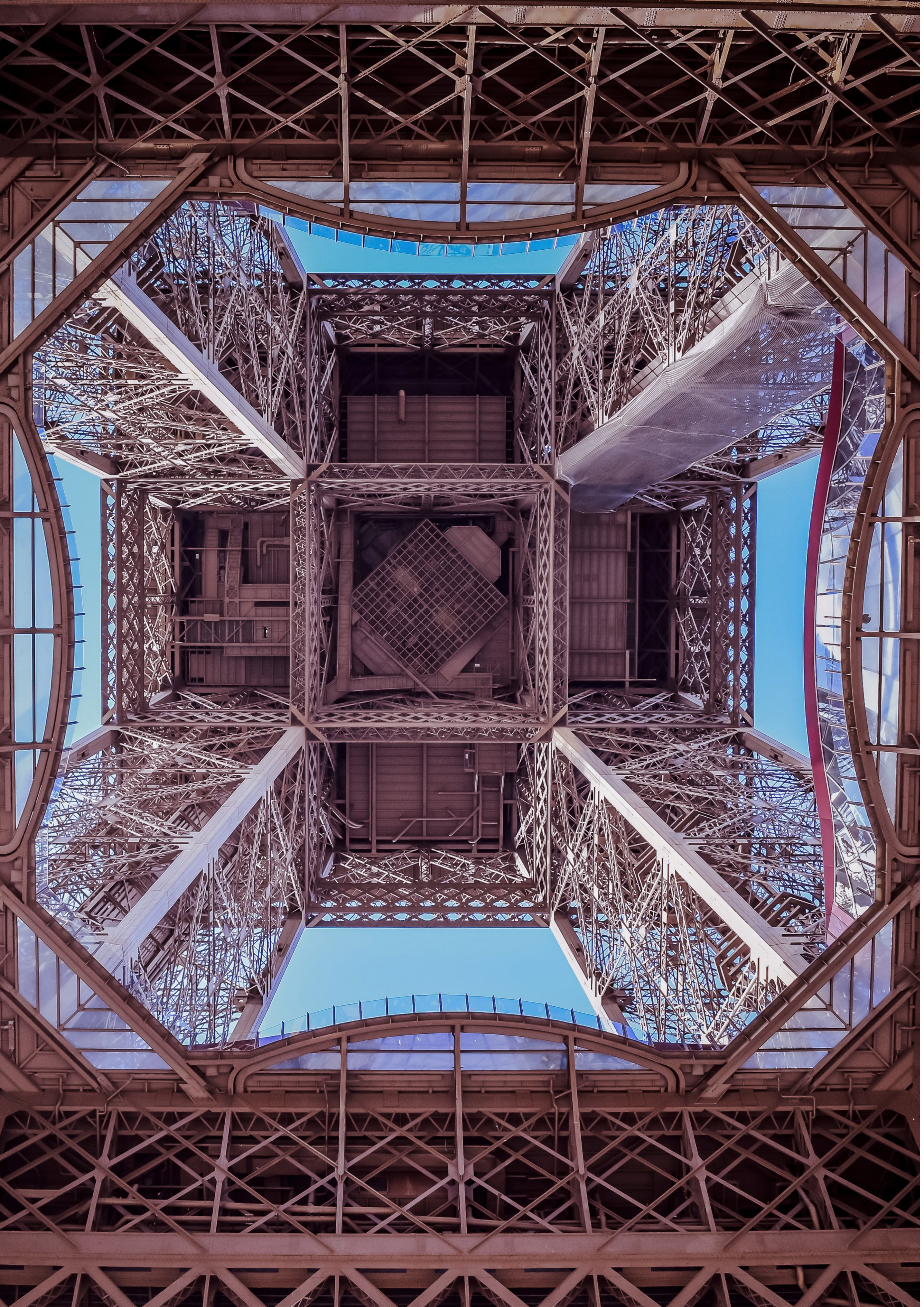


THE BROADCAST BRIDGE
Connecting IT to Broadcast

A Practical Guide To RF In Broadcast :

Part 2 - Bands, TX, RX & Radiation

A Themed Content Collection from The Broadcast Bridge

Themed Content Collection

Contents

Introduction

By Tony Orme. *Editor at The Broadcast Bridge.*

This is the second of a multi-part series which serves as a reference resource for broadcast engineers. It covers the science and practical applications of RF technology in broadcast.

Broadcasting has encountered more technology change over the past thirty years than many of us care to think about. Analog has changed to digital delivery, SD has changed to HD and 4K, and sound is transitioning to deliver higher levels of immersive experience through object and surround sound. But the one consistent technology that has stood the test of time is RF.

RF differs from most other broadcast technology as it's fundamentally analog. As the laws of physics haven't changed in the past hundred years, then the underlying rules that govern all RF systems haven't changed either. But what has changed is how we use RF in the context of modern broadcasting along with our understanding of how waves propagate through the universe.

Broadcasting has always driven technology to its limits, and this is certainly the case with RF. Morse devised the first channel coding system ninety years before Shannon formalized his achievements through information theory. And this in turn led to the development of the highly efficient coding systems that we use in modern broadcasting such as CODFM and 5G-NS.

Our RF understanding is sure to improve for as long as users continue to use mobile devices.

A Practical Guide To RF In Broadcast is a four part series with three articles per part.

Available now:

Part 1. History, Modulation & Regulation

Part 2. Bands, TX, RX & Radiation

Future parts due in 2023:

Part 3. Planning Tuning & Monitoring

- Transmitter Plant Planning
- Tuning and Monitoring Transmitters
- RF System Monitoring

Part 4. Codecs, Facilities & The Future

- Codecs and Encoding
- Other Radios in TV Stations
- The future of OTA TV

RF Spectrum Bands - From DC To Cosmic Rays

By Ned Soseman. The Broadcast Bridge.

Younger broadcast engineers who understand RF spectrum, technology, hardware, and regulations possess valuable knowledge and skills that are difficult to find.

Consumer HiFi salespeople sometimes jokingly brag that their most expensive audio gear's bandwidth is DC to daylight. Sound is in fact pressure waves mechanically generated and propagated through a solid, liquid or gas. Humans can only hear from about 18 Hz to approximately 20 kHz. Some animal species can hear higher and lower frequencies. The sound of a 'flat' premium HiFi system is controlled more by how well the loudspeakers couple with the air than by wideband circuitry.

The electromagnetic spectrum covers from a few cycles (Hz) above DC to light and beyond. Like sound waves and light waves, radio waves are also affected by reflection, refraction, diffraction, absorption, polarization, and scattering. Nearly all electromagnetic medium wave (300 kHz to 30 MHz) radio waves begin as vertically polarized ground waves propagating parallel to the Earth's surface.

Ionospheric Wild Card

The ionosphere is at an altitude of approximately 30 to 600 miles and gets its name because it is ionized by solar radiation. Ionization depends mainly on the Sun and its Extreme Ultraviolet (EUV) and X-ray irradiance which is affected by sunspot activity. Some ionospheric layers can attenuate radio waves while other layers can reflect them, all depending on states of ionization. On the AM broadcast band at night, ground waves can be reflected long distances by the ionosphere. This phenomenon is known as skip or skywave. Most overseas shortwave communications are between 3 and 30 MHz and rely on ionospheric skywaves for long-distance.

Sporadic E propagation (E-skip) is a more random form of radio skip that uses ionospheric 'clouds' of ionized metals from micrometeoroids temporarily appearing at low altitudes of about 50-100 miles that usually don't refract radio waves. E-skip affects signals between approximately 20 to 150 MHz including FM and TV low VHF channels, and it can result in temporary reception using an average antenna of distant broadcast stations as far away as 1400 miles. E-skip is somewhat periodic and seasonal, peaking near the summer solstice in both hemispheres.

F2 propagation (F2-skip) is the occasional refraction of broadcast signals off the F2 layer of the ionosphere. It is rare compared to E-skip, but it can refract signals thousands of miles beyond their intended broadcast market, much farther than E-skip. F2-skip typically affects signals in the same frequency range as E-skip. Stations occasionally get reception reports from remarkably distant locations due to Sporadic E and F2-skip conditions.

M, MM & MHz

Frequencies can be described by wavelength or by time. Wavelength is the distance over which a wave's sinusoidal shape repeats, typically between peaks or zero crossings, measured in meters or millimeters. Time is the frequency of the oscillation cycles of the current in an electromagnetic field measured in Hz, kHz, MHz, GHz, and THz. The THz band covers from 0.3 THz (300 GHz) to 3 THz. Wavelength is inversely proportional to frequency. Compared to longer waves, shorter waves require more radiated power to deliver equal signal strength over equal distances.

Usable Spectrum

The usable electromagnetic spectrum for radio communication is from about 20 kHz to 300 GHz. The ITU considers extremely high frequency (EHF) to be from 30 to 300 GHz, which is where an extensive amount of RF R&D is now funded and focused. EHF radio waves are wavelengths between ten and one millimeter called millimeter (mm) waves. Incidentally, a 1-millimeter amateur radio

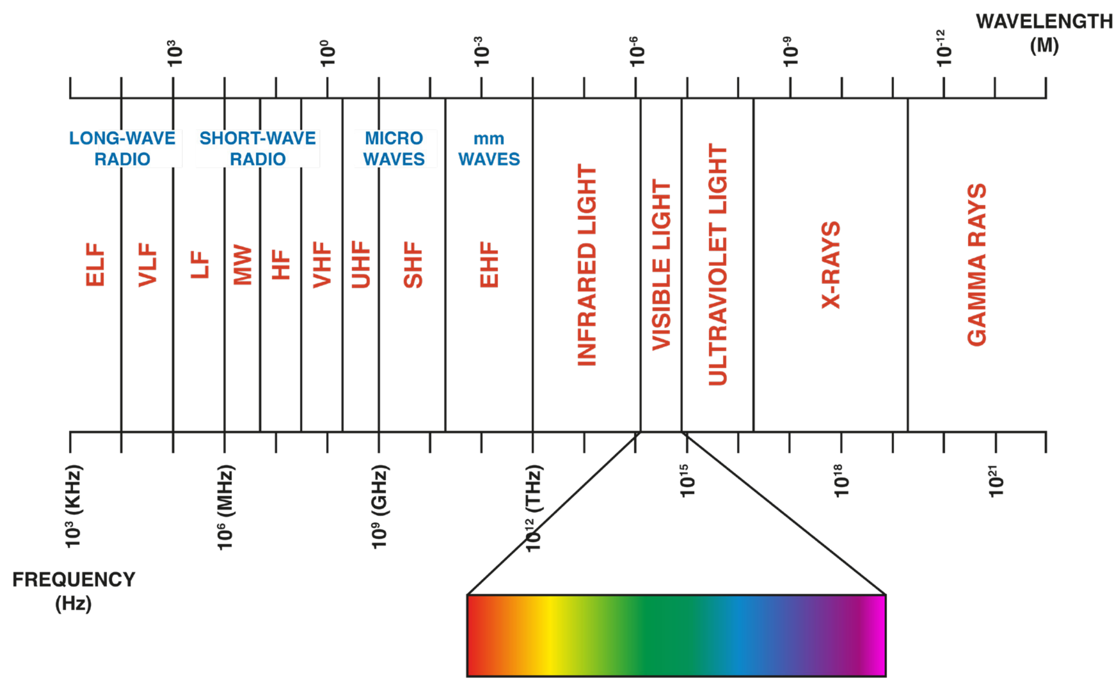


Figure 1 – The higher the frequency, the greater the energy the waves must contain to propagate in conditions other than a vacuum. Electromagnetic-type ionizing radiation begins at the upper extreme of ultraviolet and extends to all higher frequencies and shorter wavelengths such as X-rays, gamma rays, and cosmic rays.

band is between 241-250 GHz. The 1 mm band world distance record is 71 miles. 1 mm amateur band record runners up in 2019 were 5.8 miles in the UK and 2.4 miles in Australia.

The mm band includes satellite communication bands such as the Ka Band from 18-27 GHz, V Band from 40-75 GHz, and W Band from 75 to 110 GHz. G band covers from 110 GHz to 300 GHz. Terahertz frequencies above 300 GHz (0.3 THz) are only useful in extraordinarily short distances or in a vacuum. Excessive air gap obliterates THz RF communications.

If you think millimeter waves are new technology, you should know that they were first investigated by Indian physicist Jagadish Chandra Bose in the late 1890s. He wanted to investigate the light-like properties of radio waves, but the long radio waves were difficult to closely observe and study. Bose managed to produce a wavelength of about 5mm by generating frequencies up to 60 GHz during his experiments, which were in progress about the same time Guglielmo Marconi was experimenting with spark gap transmitters.

Marconi's first, crude, spark gap transmission across the Atlantic wasn't until 1901. The transmission was three repetitive clicks that Marconi knew in advance to listen for in the static. The signal center frequency of the signal was about 850 kHz, based on the length of the antennas.

Radio Propagation

Marconi's vision was focused on trans-oceanic wireless telegraphy. His early radio experiments were all conducted during the daytime, and the strength of his 850 kHz transmission predictably diminished with distance. He later discovered skywaves were regularly absorbed by the ionosphere in the daytime and refracted back to earth at night. When nighttime skywave propagation patterns were identified and understood, progress in long-distance wireless communications accelerated.

Early radio signal transmissions were typically specified in meters, referring to the length of the radio wave, and wavelength was also the origin of the radio terms long wave, medium wave, and shortwave. Portions of the radio spectrum reserved for specific purposes continue to be referred to by wavelength to this day, such as the mm band, amateur radio bands, and international broadcast bands known as 41, 31, 25, and 19 meters, for example.

Antennas work best when they measure a simple fraction of the wavelength to be transmitted or received. Tuned antennas are typically half-wave or quarter-wave in length. For example, the wavelength of an AM radio broadcast signal at 1 MHz (1000 kHz) is 299.792 meters, which is the reason most AM radio broadcast 'quarter wave' transmitting antennas are about 250' tall.

Ham Radio Advantage

My father's friend was the ham radio operator who got me interested in radio. I was hooked the moment I saw the violet glow of the mercury vapor rectifier tubes in his transmitter get brighter when he spoke into his mic. I got my Novice Amateur Radio License when I was 14. Shortly thereafter I got my first and last RF burn. Ham radio was an excellent RF learning experience because hams like to help one other and the common denominator is RF. Nearly all the engineers at the first TV station that hired me were amateur radio operators.

One of the first things I learned about radio was signal propagation. All I knew about RF propagation before becoming a ham was that I could hear distant stations on AM radio at night, and that the TV antenna or rabbit ears must be critically adjusted for minimum ghosting.

Listening and experimenting taught me the propagation characteristics of the amateur radio bands of 80, 40, 20, 15, 10, 6, and 2 meters, as well as the 220 MHz and 440 MHz ham bands. The propagation on each band between 80 and 10 meters and the international shortwave bands in between was predictable and varied between skywave and groundwave by band and time.

Ubiquitous in broadcast TV operations is the Global Positioning System (GPS). All GPS satellites operate at the same two frequencies, 1.57542 GHz (the L1 signal) and 1.2276 GHz (the L2 signal). Most TV transmitter exciters and some digital and IP gear require a GPS reference signal to operate. A climbing weed that grows to cover a simple outdoor GPS antenna mounted on a pole can knock a TV transmitter off the air.

Band Properties

Radio waves at different frequencies behave differently at different times during a 24-hour cycle, mostly due to ionospheric conditions. Long wavelengths at frequencies below approximately 2 MHz are generally considered ground waves except when the ionosphere refracts or reflects them at night.

Transmission and reception of distant signals between approximately 3 MHz to 30 MHz is controlled by the ionosphere. Different bands in that range are most active with distant signals during different times of the day and night. For example, distant signals from Japan or Australia may appear and then disappear on the same band that also temporarily carries signals from South America at another time during a 24-hour cycle.

Shorter wavelengths above 30 MHz don't bend with the Earth. Higher frequencies rarely reflect off the ionosphere except during Sporadic E propagation and are nearly always limited to line of sight. Above about 500 MHz, moisture in and on trees and leaves attenuates signals. The higher the GHz the more a signal

$$\underset{\text{(WAVELENGTH)}}{\lambda} = \frac{C \text{ (WAVE SPEED)}}{F \text{ (FREQUENCY)}}$$

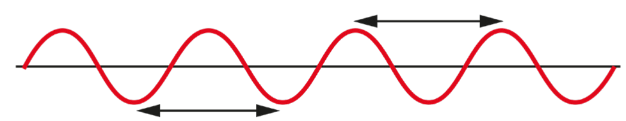


Figure 2 – Frequency and wavelength are interrelated and both influence how a radio signal propagates. Frequency is a precision objective measurement. Wavelength is a math formula with different Constants for the speed of sound and light measured in meters. RF wavelength = 299,792,458 meters per second /frequency in Hz. Audio wavelength = 335 meters per second/frequency in Hz.

is attenuated by metal, walls, skin, and eventually atoms in the atmosphere.

BAS Bands

Broadcast Auxiliary Service (BAS) authorization is available to broadcast station licensees and to broadcast or cable network entities. Certain entities involved in television and motion picture production activities are also eligible for Low Power Broadcast Auxiliary authorizations. BAS bands are protected from interference because transmission requires a license and broadcasters are the local frequency coordinators.

BAS stations are typically used to relay or backhaul broadcast aural and TV signals. It is mostly used for studio-transmitter links (STL), transmitter-studio links (TSL), ENG and live EFP feeds and backhauls. BAS also includes mobile TV pickups and remote pickup stations which relay signals from a remote location back to the studio when a multiple hop is the only way to get a stable signal to the studio.

Broadcast Auxiliary Services bands are 1990-2110 MHz and 2450-2483.5 MHz (2 GHz), 6875-7125 MHz (7 GHz), and 12.7-13.25 GHz (13 GHz). Licensees must get a waiver of the rules to transmit with digital modulation in these bands. Digital modulation is allowed in the 6425-6525 MHz, 17.7-19.7 GHz and 31.0-31.3 bands. More information is available from the: Federal Register :: Broadcast Auxiliary Service Rules

Transmitter & Receiver Fundamentals

By Ned Soseman. The Broadcast Bridge.

The electromagnetic spectrum makes wireless communication and broadcasting possible. Mastering and managing the electromagnetic spectrum while complying with government technical regulations and industry standards is the responsibility of every broadcast engineer.

Naturally occurring radio waves are generated by lightning and some celestial objects like the sun. Artificial radio waves are generated by an electronic transmitter, connected to an antenna that radiates radio waves when excited by the RF alternating current from the transmitter. The radio waves are received by another antenna connected to a radio receiver, which amplifies and processes the received signal.

An unmodulated transmitter broadcasts radio waves on a specific frequency known as the carrier signal. The most basic technology to modulate a carrier signal is to turn it on and off, which is only useful for Morse code. Adding information such as sound, video or data to the carrier signal requires one or more of several types of signal modulation.

Amplitude modulation (AM) adds information to the carrier by varying its amplitude and is susceptible to atmospheric static. Frequency modulation (FM) adds information by slightly varying the carrier signal's frequency and unaffected by atmospheric static. Analog TV used AM modulation for video and FM modulation for audio. DTV, including the latest generations of DVB and ATSC 3.0 are moving away from 8VSB modulation to orthogonal frequency-division multiplexing (OFDM) to encode (modulate) digital data on multiple carrier frequencies.

Transmitter Basics

The signal from every transmitter begins in an electronic oscillator and possibly frequency multiplying circuitry that generates the carrier wave on the desired transmitting frequency. The frequency stability of the carrier wave signal is crucial for compliance and reception. The oscillator can be locked to a resonant quartz crystal reference, GPS, or a synthesized frequency oscillator. Most transmitters, including TV broadcast transmitters, consist of three separate sections: The exciter, the power amplifier (PA) including high-current power supplies, and the output filter.

A broadcast transmitter exciter, also known as the modulator, is essentially a tiny TV transmitter with an RF output typically rated in milliwatts. It converts content from a source such as a control room or studio-transmitter-link (STL) into a modulation signal that excites the broadcast carrier with the preferred modulation type. The RF output of a TV exciter connects to one or many RF amplifiers in the transmitter cabinet depending on the transmitter design and total transmitter power output (TPO).

Modern TV transmitters use solid-state power amplifiers, each typically powered by an independent low voltage power supply. Until solid-state TV transmitters became available, UHF TV transmitters used an inductive output tube (IOT) for the PA that required a minus 35 KV power supply to operate. TV transmitters have become significantly less dangerous and easier to repair. Each cabinet of old TV transmitters using high voltage PA tubes usually included a three-foot-long copper hook attached to the rack ground with 5' of AWG 3/0 to discharge large capacitors or free a shocked companion from certain electrocution and a constant reminder of the danger inside.

Broadcast TV transmitters are built to order for a specific TPO on VHF or UHF TV bands. Each PA is typically plugs in a master chassis and is hot-swappable. Most solid-state PAs put out approximately 750 watts with some additional headroom, and they are usually powered by individual 50 V hot-swappable power supplies. Broadcast TV transmitters are also either air- or liquid-cooled often depending on the transmitter building cooling system and the heat load of the transmitter at full power.

Harmonic Filtering

The output of the RF amplifier(s) must be filtered with a low-pass filter and checked for spurious emissions such as harmonics with an RF spectrum analyzer. A RF harmonic is an unwanted signal often occurring at multiples of the original carrier frequency. Harmonics from the popular 500-600 MHz DTV band can interfere in bands used for other purposes, such as cell phones and Wi-Fi. You'll hear from who your signal interferes with because they have spectrum analyzers, too. The output of the filter connects to the antenna transmission line.

Multiple PA TV transmitters provide individual monitoring of the power output of each PA module for preventative maintenance purposes. All TV transmitters are typically monitored for legal compliance of frequency, loudness, and modulation levels, TPO before and after the filter, and the antenna voltage standing rave ratio (VSWR).

VSWR

VSWR is the ratio of minimum to maximum voltage along a transmission line ½ wavelength or longer. A VSWR of 1:1 is the theoretical goal everyone wants, but many physical factors such as transmission line lengths and tiny impedance mismatches make a perfect 1:1 difficult to achieve.

Most optimal TV broadcast transmitters operate at under 1.25:1. VSWRs above about 2:1 can be toxic for transmission lines, filters, and transmitters. If a SWR mysteriously increases, the problem is in the transmission line or antenna. Something happened to cause the transmission line to arc, maybe a loose connection or a lightning strike, or a bad actor shooting at tower lights hit the transmission line. Things happen, and trying to pump full power into a high SWR load will create more problems. Reduce the transmitter power and identify the source of the VSWR problem ASAP.

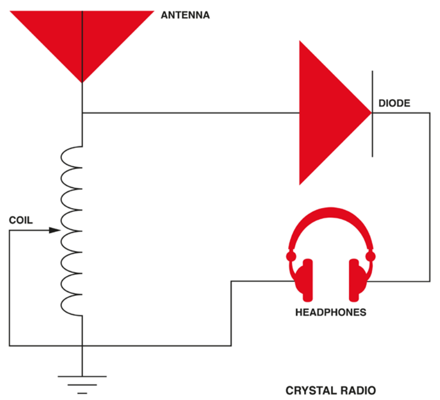
Receiver Basics

A story about transmitter fundamentals wouldn't be complete with mentioning receivers. The first were crystal radios used to receive Morse code from spark-gap transmitters operated by early amateur radio experimenters. Before modern semiconductor diodes, a crystal radio used a "cat whisker detector" for the diode.

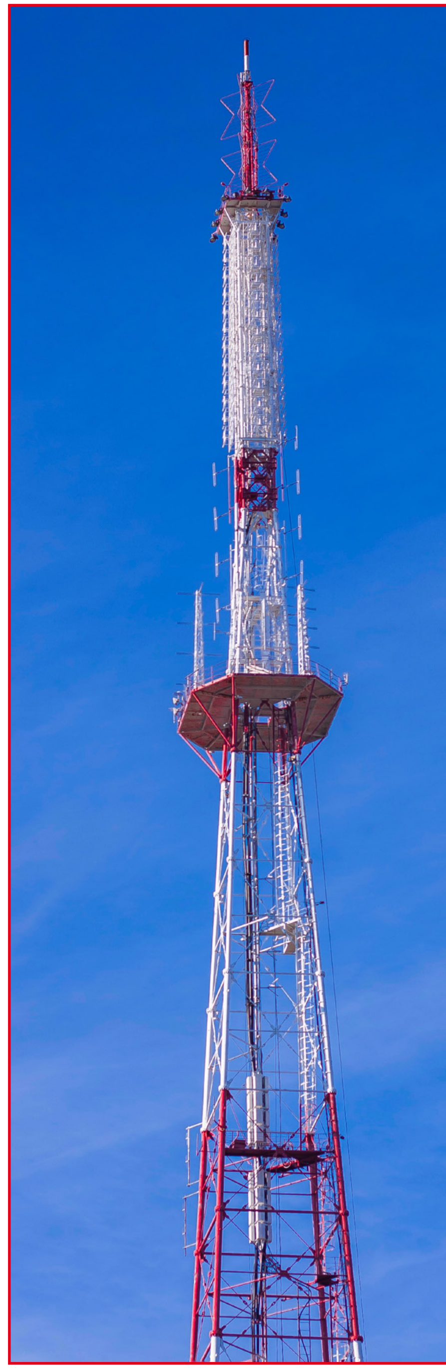
Crystal radios need a long-wire antenna to receive a signal that can generate the microwatt or nanowatts necessary to make sound in a headset. Crystal radio selectivity is poor because it has only one tuned circuit and technology was limited to frequencies below about 500 kHz. Until Major E.H. Armstrong introduced the local oscillator and superheterodyne receivers in late 1919, everything above 500 kHz was considered shortwave and beyond the technology of early vacuum tube amplifiers.

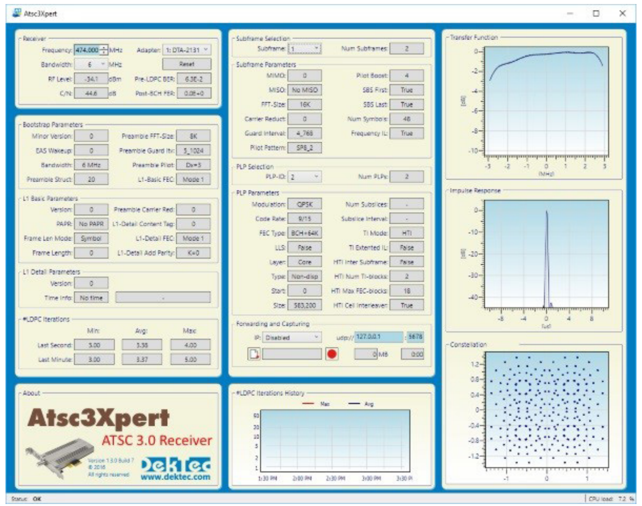
The term heterodyne means 'generated by a difference in frequency.' A heterodyne created when two signals are mixed produces two new signals, one is the sum of the mixed signals frequencies, the other is the difference. The new signals are also known as 'beat' frequencies. Only the difference signal is typically used in heterodyne and superheterodyne radio receivers. In them, radio stations are tuned in by varying the frequency of the local oscillator to produce a difference signal on a fixed frequency known as the intermediate frequency (IF).

When commercial radio broadcasting began a century ago, the most popular domestic radios were of tuned radio frequency (TRF) design. They were cheap to build and easy to operate. A TRF receiver uses one or more tuned RF amplifier stages followed by a detector (demodulator) to extract the audio signal, and usually included an audio amplifier. The local oscillator tube and IF circuitry was cost prohibitive until improvements in vacuum tube technology and a growing number of broadcast stations created a demand for better and less-expensive home radio receivers.



The most basic AM radio crystal radio uses the capacitance of the antenna to make a tuned circuit with a coil, and uses a diode powered by the radio signal to demodulate AM radio to audio.





Atsc3Xpert in-depth RF Analyzer for ATSC 3.0

A New Era In RF Analysis

By Stephane Billat. *GM at DekTec America.*

These days, it's quite challenging to come across an article without any mention of cloud computing, IP-based transport, or the seismic shift away from traditional broadcast models.

Yet, amidst the digital buzz, the critical role of RF technology in underpinning data and video transmissions across distances often gets overlooked. From cell phones to Wi-Fi, Bluetooth, 5G, digital radio, GPS, and even cable internet, various forms of modulation are employed to transfer audio, video, and data to our smart devices. In this grand symphony, the global industry employs over 20 unique modulation schemes, each hitting the high notes of efficiency and robustness, just for delivering AV and data to an array of platforms.

For professionals involved in RF research, field testing, monitoring or equipment development, performing in-depth RF signal analysis is critical to delivering high-quality services or crafting effective solutions. Our offering, the DekTec DTU-331, a compact and portable RF probe, effectively addresses this need. Designed for use with a laptop over a single USB-3 connection (no need for a power supply), it is ideal for fieldwork.

SDR Technology for Advanced Measurements

Offering users advanced, portable RF analysis capabilities, including support for emerging standards, the DTU-331 assists in validating new equipment, troubleshooting, recording live signals, and also fosters innovation and learning in broadcasting, research, and education.

Equipped with two tuners (wide-band for satellite and small-band for cable/terrestrial) and a frequency mixer, the DTU-331 captures signals across a broad frequency range from 42 to 3220 MHz. Its utilization of Software-Defined Radio (SDR) technology is its stand out feature, offering flexibility and capabilities beyond traditional hardware-based demodulators.

The power of SDR lies in its software-centric approach to demodulation. As all I/Q samples are available to the analyzing software, our probe offers precise and unique RF measurements not available in any chip-based demodulator solution.

This flexibility allows the DTU-331 to incorporate not just standard measurements such as Modulation Error Ratio (MER), spectrum analysis, and constellation diagrams, but also advanced measurements like impulse response and transfer functions. Users gain a comprehensive understanding of RF signals and system performance.

The SDR architecture allows the RF probe to adapt to changes in existing standards and to accommodate emerging ones, ensuring the device maintains its future relevance and efficacy.

Applications In Broadcast

For complex modulation schemes such as ATSC 3.0 or DVB-T2, this super compact receiver can analyze both physical layer and upper layers, up to the audio and video. This allows users to get a complete picture of all aspects of the signal.

Broadcasters can employ the DTU-331 along with the Atsc3Xpert™ and StreamXpert™ Windows software to validate signals during the deployment of new equipment or transmission systems. Thanks to its portability, signal reception conditions can be checked in various locations with just a laptop, a DTU-331, and an antenna.

The device's ability to record raw I/Q signals lets engineers capture live signals and recreate complex RF scenarios in the lab. These signals can be replayed using the DTU-315 companion portable modulator, bringing the live signal to a lab anywhere in the world.

The DTU-331 can also analyze satellite signals. A demodulator is also available for the DVB-CID spread-spectrum modulation scheme used in satellite communications to provide a unique identification code for each carrier. This way, operators can trace the origin of satellite carriers, mitigate interference, and coordinate spectrum resources to ensure the quality of satellite services.

Applications Beyond Broadcasting

The DTU-331also offers considerable utility in non-broadcast settings thanks to its general-purpose design. It facilitates in-field recording of RF signals as I/Q samples and supports custom analysis via specialized software tools such as MatLab, or via your own custom analysis software. As long as the RF signal is located in the 42-3220 MHz band and less than 60MHz wide, our unit can capture it!

The DTU-331 is fully supported in our standard SDK, allowing 3rd party organisations to develop their own application for internal use or for resale.

This flexibility positions the DTU-331 as an adaptable tool for a broad range of applications. It aids in the development and fine-tuning of new modulation schemes, reception algorithms, error correction techniques, and transmission protocols, thereby extending its utility beyond traditional broadcasting environments.

The Principles Of RF Radiation

By Ned Soseman. The Broadcast Bridge.

In 1865, James Clerk Maxwell published "A Dynamical Theory of the Electromagnetic Field." It postulated that electric and magnetic fields travel through space as waves moving at the speed of light in the same medium, leading to his prediction of radio waves.

The first radio antennas were built in 1888 by Heinrich Hertz. In 1895 Guglielmo Marconi began development of antennas for long-distance wireless telegraphy for which he was awarded a Nobel Prize in 1909.

Transmission antenna design depends on resonance to maximize the radiation of electromagnetic radio waves. One of the simplest and most widely used transmitting antennas is the ½ wave dipole. It consists of two ¼ wave elements, oriented end-to-end, and center-fed by the transmission line. In each ¼ wave element, current from the feed point will change phase by 90° by the time it reaches the end of the element. The end reflects the signal by 180° and it is delayed another 90° as it returns along the element back to the feed point. This process creates a standing wave in the element with the maximum current at the feed point. At any instant, one of the elements is pushing current into the transmission line while the other is pulling current out.

The ¼ wave elements create a series-resonant electrical circuit due to the standing wave. At the resonant frequency the standing wave has a current peak and a voltage minimum at the transmission line feed point. The radiation pattern of a ½ wave dipole is perpendicular to the elements and weak in the axial directions. The problem with a single ½ wave dipole is that it is omnidirectional and therefore has no gain.

Antenna Gain

Antenna gain is produced by concentrating radiated power into a particular solid angle of space (called lobes) at the expense of power reduced in undesired directions (called nulls). It is not the same as amplifier "gain" which implies an increase in power. Antenna gain is produced by focusing the RF radiation using multiple antenna elements and phasing. Antenna gain benefits both transmission and reception.

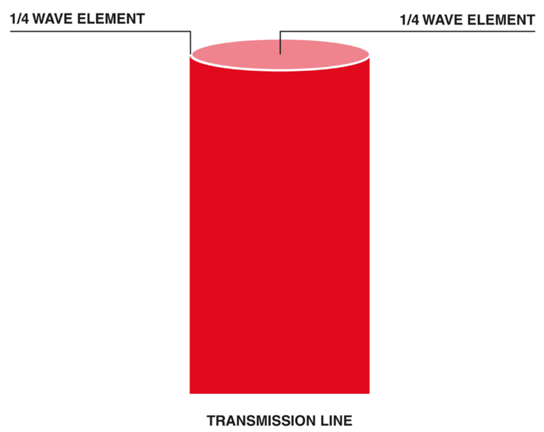


Figure 1 – A simple dipole is the most common transmission antenna design.

All antennas must interact with electrical ground to work. For example, one side of a ½ wave dipole is always grounded. A monopole antenna, also known as a whip or rubber ducky, commonly used in walkie-talkies, produces a weak, omnidirectional signal that inductively interacts with the ground beneath it.

An AM broadcast tower is often the antenna, isolated from ground by a ceramic insulator. The 'ground plane' at many non-directional AM broadcast towers is often buried ½ wavelength 6" copper ground straps, extending radially from the tower base, designed to direct the radio waves towards the horizon.

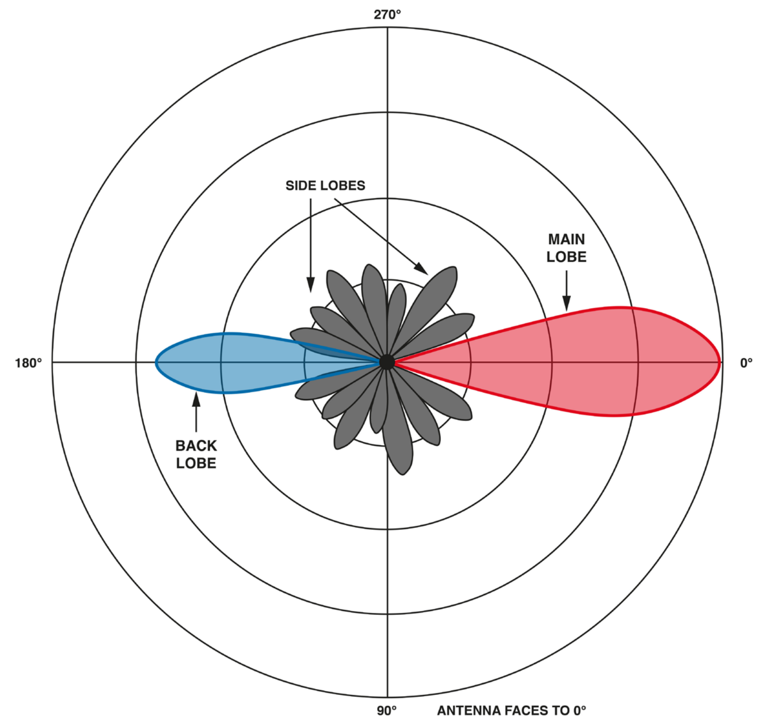


Figure 2 – Polar plot shows the lobes and nulls of a highly directional, high-gain, Yagi UHF receiving antenna. Most broadcast TV signal lobes aren't nearly as intense.

TV Transmitting Antennas

The choice of TV RF transmission system components is a function of fully covering a DMA at licensed full power while avoiding interference with other stations. Selection of RF hardware is a scientific process of elimination that typically requires an experienced engineering consultant to design the best and most compliant RF system possible. Every TV transmission facility and project is unique.

Nearly all TV transmission antennas are variations of the dipole. A turnstile or crossed-dipole antenna consists of a set of two identical dipole antennas mounted at right angles to each other and fed in phase quadrature, making the two currents applied to the dipoles 90° out of phase. When mounted horizontally the antenna looks like a pedestrian turnstile. The antenna can be used in two modes. In normal mode the antenna radiates horizontally polarized waves perpendicular to its axis. In axial mode the antenna radiates circularly polarized radiation along its axis.

Specialized normal mode turnstile antennas used in TV broadcasting are often called super-turnstile, or batwing antennas. Axial mode turnstiles are widely used for broadcasting in both the VHF and UHF TV bands for circular polarization propagation. They are also popular for satellite earth station antennas because circular polarization is not sensitive to the orientation of the satellite antenna in space.

A bowtie antenna, aka butterfly antenna, is a dipole with triangular or arrow-shaped elements with the feed point where the triangles meet. The triangles can be cut from sheet metal with solid metal centers, or they can be created by two ¼ wavelength wires with their far ends connected outlining the shape of a bowtie.

Slotted coaxial antennas have many advantages over traditional broadband panel antennas including much smaller size and wind load, higher reliability and a greater degree of azimuth and elevation pattern flexibility. Many side-mounted slotted antennas are designed for single channel operation.

High power, top mounted, slotted coaxial broadcast antennas can be used for broadband multi-channel applications. Slotted antennas provide a lower cost, lower wind load and more reliable alternative to panel antennas. This is accomplished with phase cancelation through multiple feeds. The effect of external transmission lines, used for the multiple feeds, on the circularity of the azimuth pattern can be minimized with parasitic tubes near the surface of the aperture.

Top mounted, top-mounted stacked arrays, side-mounted, side-mounted center-fed, delta wing (dual batwings) panel antennas for UHF and are commonly used in horizontal, elliptical, or circular polarization with up to 14 dB gain. Beam tilt can be electrical or mechanical.

Transmission Line Types

Typical coaxial transmission lines for TV range from flexible and semi-flexible to rigid, from 7/8” to 12” diameter, as well as rectangular waveguide for high power UHF stations. Waveguide has no center conductor. Rigid and waveguide doesn’t bend. 90° elbows and couplers are used to turn corners.

Typically, TV transmission lines are kept free of moisture with some gentle positive pressure from a regulated nitrogen bottle, a nitrogen generator, or a dehydrator. Moisture in a transmission line can increase the VSWR.

Filters, Combiners & Directional Couplers

VHF Harmonic Filters, UHF Harmonic filters are designed for indoor use and provide high rejection of harmonic products outside the 6 MHz TV band. Waveguide filters are built for a specific operating frequency. Tunable standard coaxial bandpass filters are used between the transmitter output and antenna system to suppress undesirable frequency products. Coaxial filters are tunable with many tempting physical adjustments, but never try it yourself. If a filter develops a problem that you get a complaint about, send it back to the manufacturer for retuning or repair.

Single channel combiners are used to combine two or more transmitter PAs to create the total power output (TPO). Standard channel combiners are used to combine two or more separate channels

This hanging mask filter is connected to the transmitter output and the antenna transmission line. Note the probes on the filter input and output to monitor power and VSWR.

on one antenna system. Types available include a constant impedance filter, a branch or starpoint combiner which uses a bandpass filter per transmitter, and a manifold combiner that combines multiple channels with a minimum spacing of two channels each.

Standard coaxial directional couplers with single or multiple probes are used to measure forward and reflected power (VSWR) before and after the filter. Motorized switches for most transmission line types can be used to switch between antennas or a dummy load.

Towers

TV towers are tall because broadcast TV signals are line-of-sight. Also, hills and valleys can block a TV RF signal by causing a ‘shadow’ that can only be overcome by raising the receiving antenna.

Towers are a broad topic, best addressed by professional broadcast TV consultants and manufacturers and entirety is beyond the scope of this chapter.

However, the most practical TV tower information is the maximum distance an omnidirectional full power TV signal will travel. Line-of-sight is equal to the square root of the height of the antenna (or eye) above average terrain times 1.225. For example, standing at sea level you can see 3 miles. The visible distance from a height of 100’ is 12.25 miles. At 500’ its 27 miles, at 1000’ it is 39 miles, and 2000’ is about 54 miles.