RADIO TECHNOLOGY MUSEUM

# RTM DOCENT'S GUIDE TO THE MUSEUM


**Version 1.1**

**April 2025**

# Table of Contents

# Section 1 – Overview - How is the Museum Organized

## Introduction

The Radio Technology Museum (RTM) showcases the history and evolution of many of the technologies that made modern communications possible. Most of those technologies are based on the sending and receiving of radio signals sent through the air - or through empty space or wires or optical fiber.[*] It is actually a museum of ***Communications History and Technology*** .

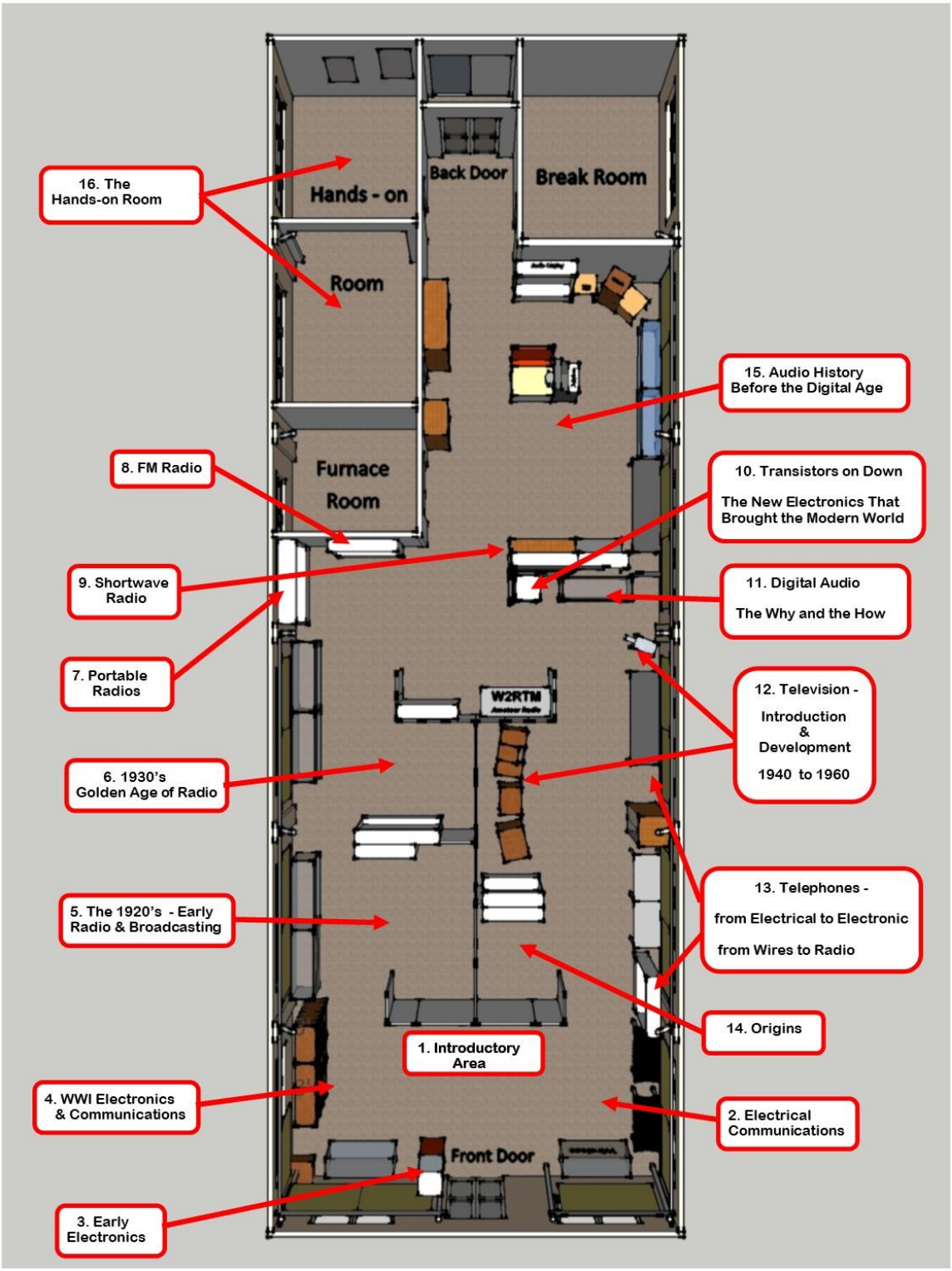
Our intention in the RTM is to not only tell museum visitors about these communications technologies or to show the visitors some of these devices and other artifacts, but also – by demonstrations and hands-on opportunities – to allow visitors to *experience* them.

The RTM is sponsored and partially supported by the New Jersey Antique Radio Club (NJARC). RTM was founded by NJARC in 2004, so many of our volunteers are members of NJARC. We should note that since the RTM is an outreach of the NJARC, it is highly recommended that volunteers remain or become members of NJARC. We welcome all volunteers who have a desire to teach our visitors about communications technologies, and to inspire new thinking about how these technologies affect their lives.

---

[*] In the 1980's, Professor Nicholas Negroponte, one of the founders of the *MIT Medialab*, predicted a phenomenon later called the "*Negroponte Switch*". The 'Switch' that he predicted was that much of the communications being delivered at that time by wires *(for example, telephone),* would someday be delivered wirelessly (by radio waves), and also that much that was then being delivered wirelessly *(for example, TV Broadcasting)*, would someday be delivered by wire (e.g., cable, fiber). Look around. We have lived through this change

# Display Areas—*Where is Everything in the RTM*



# Section 2 Brief Descriptions of the Display Areas

## Beginnings of Radio Communications

## Area 1 - Introductory Area - Marconi at the Belmar Site

The Introductory Area near the FRONT door of the museum visitors a snapshot of the history, purpose and content of the RTM. It should be especially useful for providing orientations to groups visiting the museum, e.g. school groups and organized groups such as clubs. This area can be used to display introductory video and graphic material, to illustrate some of the history of the site and museum, and to provide a sampling of the kinds of displays and topics that visitors can expect to find here.

This site was founded by Guglielmo Marconi in 1913. The lore is that Marconi called this station “Belmar” because he got off the train at the Belmar railroad station. This area shows some of the history of the founding and construction of the Marconi Belmar Site.

Marconi was born in Italy. As a youth he had heard of work by James Clerk Maxwell that had proven that wireless communication was possible. In the 1880’s, he was especially intrigued by reading about Heinrich Hertz’s wireless experiments and began experimenting himself with wireless communication. His early experiments were somewhat successful, but neither his father nor the Italian Navy whom he thought might be interested, would pay for improving his apparatus. However his mother, Annie Jameson of the Jameson Whiskey family (and fortune), offered to take him to England and provide him with some introductions. The move was very successful, both in terms of getting British investors and Scientists interested in his work, but also in that he successfully improved his apparatus to operate over hundreds of miles. Consequently, he remained in Britain and continued his work, and eventually founded a number of businesses to take advantage of his technical successes.

Between 1900 and 1913, he had been very successful in developing a company, *Marconi International Marine Corp. (MIMCO)*, which provided ship-to-shore communication services for marine services around the world. Over the years,

# Section 2 – Descriptions of Display Areas

Marconi's communication services would save many lives. In 1913, Marconi started another business. His new company, *Marconi Wireless Telegraph Company of America (MWTCA),* began building wireless stations around the world to compete with the undersea cable companies which were providing telegraph service between continents. The Plan for each Marconi station was to locate the transmitters and receivers several miles apart so that the receiver could be operated even while the station was still transmitting. This location, the Marconi Belmar Station, was one of those stations. It was a receiving station and was paired with a transmitter at the Marconi New Brunswick Station. In actuality. It could be called the Marconi Belmar/New Brunswick Station. Together, their purpose was to provide 2-way wireless communications services between the United States and Britain. This Area of the museum provides some artifacts and other information about that development.

## Area 2 - Electrical Communication

This Area, also in the front of the museum, displays some of the earlier technologies that provide Electrical Communications based on such things as electromagnets and electric currents flowing through wires. Examples include the telegraph and the telephone.

Even 'wireless' transmitters such as those Marconi used and a model of which is shown in this Area, generated their wireless signals simply by producing electric sparks, so they are fundamentally electrical, but not electronic in nature. The primitive signals that were produced *did* pass through the air but they covered a VERY wide band of frequencies.

Any receiver within many miles of a spark transmitter and trying to receive a signal from another transmitting station would find it impossible. In terms of an AM radio of today, operating a wireless spark transmitter near an AM receiver would prevent hearing ANY radio stations on that radio. It was for this reason that all Marconi stations were built, like the Belmar/New Brunswick Station, with the receiver and transmitter spaced many miles apart. Another issue was that they transmitted what was essentially electrical 'noise', so they were only capable of sending Morse code: that is, simple on-and-off signals. They were not capable of carrying other signals such as voice or music.

The familiar word "electronic" refers to the manipulation and control of the flow of electrons in such devices as vacuum tubes and their successors. Such concepts were a later development than those shown here in Area 2. Refer to Area 3 of the museum for more information on that topic. So neither telegraph, telephone nor spark transmitters use any form of what we now call 'electronics' which would later provide solutions to the interference and morse code-only problems. These solutions awaited the development of the vacuum tube, which occurred around 1910.

## Area 3 - Early Electronics – Introduction of the Vacuum Tube

Here we show items from the birth of electronics – notably, early versions of vacuum tubes. In the 1880's, Thomas Edison – the inventor of the light bulb - observed that the glass inside his light bulbs would become blackened when they were used. He experimented with ways to fix that, and it was discovered that inserting a piece of metal connected to a positive voltage would prevent the blackening – this discovery was later dubbed the 'Edison Effect'.

When in 1897 scientists discovered the electron which is a negatively charged particle, the explanation for the Edison Effect became clear – negatively charged electrons were being emitted from the light bulb filament, and were attracted to the positively charged metal plate rather than being deposited on (and blackening) the inside of the glass bulb.

So, you might say that a vacuum tube is a glorified light bulb. The first well-known but extremely primitive vacuum tube which had some limited uses was made in 1906 by Ambrose Fleming, an English scientist. Around 1910 Lee DeForest of the US developed a much more versatile tube that among other things, could amplify electrical signals – for example the voice signals from a telephone. He named it the 'Audion'.

Why were vacuum tubes and other 'electronics' important? Consider the following. As we saw in Area 2, wireless transmitters of the 'spark' variety were VERY wide band. Wireless transmitters using vacuum tubes can produce a radio signal by a process known as 'oscillation', produced a signal that is well-suited to carrying voice, music and later, TV images and more. Then another vacuum tube used as an amplifier could make the sound easily heard. Before this, ALL of the power that reached a the headphones over a listener's ears, had to come through the air from the transmitter which might be hundreds of miles away. Now, the receiver using tubes as amplifier could take a very weak signal that had come through the air, and make it loud enough to be heard comfortably. Even to power the new 'loudspeakers' and fill a room with sound. Electronics had arrived, and electronics based on vacuum tubes dominated communications technologies until well into the 1960s.

## Area 4 - The World War - Electronics and Communications

The First World War (1914 – 1918) is sometimes described as the first 'Technology War'. One situation in which the importance of technology is undeniable is in communications. For the first time in warfare there was electrical communication, however primitive and tenuous, between headquarters and the front lines. There was wireless communication among headquarters. There was wireless communication from ship to shore, and sometimes even to the flimsy airplanes of the day. And there was communication among continents.

Before the War began in Europe in June of 1914, Belmar/New Brunswick were still in a construction and testing phase, and had not yet begun to handle commercial messages. Once the war began, since the Marconi Company was a British company and the US was a neutral nation (until April, 1917), the US government did not permit the Marconi company to operate the station. Instead, the US Navy was assigned to control the Belmar/New Brunswick sites.

This area of the museum displays a collection of some of the Navy (and foreign) radio communications systems. If you look closely, you might notice a progression from relatively simple devices with wires and coils and only capable of sending and receiving morse code, to devices with multiple vacuum tubes and capable of carrying voice communications. Some examples: the large Navy receiver from the early days of the war when communications was strictly code (left side of the large display case) has only a single vacuum tube, whereas those from later in the war (right side of case) have multiple vacuum tubes and can transmit and receive voice. During the war, Electronics had taken over from electrical communications. By its end, devices such as these primitive 2-way radios were in use. This would have a huge impact during the 1920's.

Another very major effect of the Navy's operation of Belmar/New Brunswick occurred at the New Brunswick transmitter location. The spark transmitter at New Brunswick was replaced by a unit developed by General Electric called an Alexanderson Alternator in 1917. The Alternator was a far superior transmitter capable of narrow-band rather than wide-band transmission, and therefore did not interfere with other signals. It could carry voice signals. This device was so advanced for the time, and so important that when the war ended in 1918, the US government did not want to return the Marconi stations to the Marconi company, and their primary concern was the control of the patents on this

alternator (and other wartime developments). This resulted in the eventual formation of the Radio Corporation of America (RCA) in 1919. RCA then purchased the (former) Marconi properties from the Marconi company. As a footnote, vacuum tubes eventually became the fundamental technology for all radio transmitters, having many advantages over the alternator. However, in the 1918 – 1920 era, the alternator was probably the better transmitter.

## Area 5 - The 1920s –Radio Broadcasting Begins

After the World War, what had been 'wireless' communications practiced only by amateurs who were able to build their own equipment, was an idea whose time had come. During the war, there had been a vast improvement in vacuum tubes which made wireless transmission of voice and music practical. people at home now wanted something to be done with it – for them. There were experiments sending music (and sometimes called 'dancing by radio'). The term 'wireless' had fallen out of favor, and replaced by 'radio', (at least in the US).

Then in 1920 the Westinghouse company in Pittsburg enlisted the services of one of its employees, Frank Conrad, who was one of those radio amateurs, to begin sending scheduled 'programs' from his amateur station 8XK. Westinghouse applied to the Commerce Department of the US Government and received what was apparently the first *Broadcasting* license, **KDKA**. The first program officially scheduled and broadcast were the results of the 1920 presidential election (on November 2, 1920), and Westinghouse began making receivers to be sold to members of the public at a local Department Store. By the end of 1920, KDKA was the only licensed station. By 1923, over 600 licenses had been issued, and the "Radio Craze" of the 1920's had begun.

This area displays some of the radios and ephemera that are the results of that event. A chart shows the growth of radio broadcasting stations from 1 (KDKA) to hundreds, in the first years of the "Craze".

During the 1920's, hundreds of manufacturers. Many never succeeded. A few, such as **Z'Nith** (later Zenith), **Philco** (originally The Philadelphia Storage Battery company), **Atwater Kent** (named for its owner, Arthur Atwater Kent who initially built automobile ignition systems), **Crosley** (for Powel Crosley, who later built washing machines, cars and other products, **RCA** (whose radios were built by *Westinghouse*, *General Electric* and others) and more, became well-known and are shown here. One of particular local interest was **Marlodyne**, marked as being made in Asbury Park (actually, it was built in Bradley Beach. Unfortunately, this was one of the companies that did not survive.

## Development of Communications Technologies– The Next Steps

Areas 1 through 5 above illustrate and demonstrate developments in communication technologies in their early years, from 1830 to 1930. The results of these developments were delivered to the general public *as Broadcast Radio*. With that as a starting point, the four Areas below illustrate some of the more important advancements in communication technologies prior to the beginning of World War 2.

## Area 6 - The 1930s and 40s - The Golden Age of Radio

The decade of the 1930's was the era of the Great Depression – in the US, this included a period when 25 percent of workers were unemployed and wages for many still-employed workers had fallen by more than 40 percent. Lingering effects of this difficult period didn't really end, and full employment return, until the early 1940's.

It was a very difficult time for America, but AM *Broadcast Radio* was one thing that nearly everyone depended upon to keep up their spirits and to provide information. For those who could afford them, the *console radios* shown here were considered fine furniture, and were the center of their homes. For those who could not afford one of these, the smaller, less-impressive and less-expensive *table model radios* were a near-necessity. In fact, although in 1930 only 40 percent of households in the US owned a radio receiver, by 1940 this had more than doubled to 83 percent.

Radio networks – CBS, NBC (red and blue), Mutual - also grew significantly during the 1930's to provide programming for those radios. The networks could afford to hire the high-priced talent that local stations could not, and the purchasers of those radio receivers reaped the benefits – listening to the programs and paying only with their annoyance at having to listen to the many advertising commercials that came with the programs.

Technological development too, continued. Shortwave communications which had only just begun by 1930, made significant technical advancements and international shortwave broadcasts grew significantly, especially as war tensions grew worldwide in the later 1930's. Note that many of the radios in this area of the museum are so-called "all wave" or "multiband" radios capable of receiving shortwave as well as standard broadcast AM stations. The reason will be discussed below, in Area 9.

## Area 7 - Portable Radios

From the inception of radio broadcasting, the thought of being able to take your radio with you - for example: to the beach or to a cabin, or even camping - always appealed to a great many people. When radio broadcasting began in the early 1920's, the power-hungry vacuum tubes that were at the heart of many of the earliest radio receivers operated only on battery power from large, heavy and sometimes messy (some spilled acid on your carpet) batteries. Carrying them along with the radio receiver was usually impractical.

In the later 1920's vacuum tubes were developed that could operate from an a-c source rather than batteries. These tubes tended to be large, created a lot of heat and still used a lot of power. (And besides, beaches and camping tents are notorious for their lack of electrical outlets. 😊 )

But by the later 1930's, vacuum tube technology had improved to the extent that manufacturers developed smaller "miniature" vacuum tubes that ran on relatively low power, and thus were able to run on smaller, lighter dry batteries. The truly 'portable' radio had arrived, for example the black and silver RCA-designed BP10 receivers, two of which are stacked to display the front and the back. These and others were advertised as 'personal portables'. This Area of the museum displays a number of such portable radios, which were comparatively small and light for the era.

A few larger and heavier receivers are also shown, notably the Zenith Transoceanic, (or 'TO') which looks somewhat like a black suitcase. Although these were more 'luggable' than portable, they more than made up for it with extra sensitivity, multiple bands to assure they could be usable anywhere at any time, ease of use and robust construction. This model was developed by Zenith at the personal direction of Cmdr. Eugene McDonald, the Chairman of Zenith. Production for civilians ceased in 1942 after the US entered World War 2, but after the war, production resumed and until about 1960 models of this receiver were highly coveted and sold very well.

When WW2 came in the 1940's, miniature tubes were an important asset in many wartime devices. Look at some of these uses – far beyond just in portable radios - in the WWII Communications Museum in hallway 9032C.

# Section 2 – Descriptions of Display Areas

## Area 8 - FM Radio

While most people familiar with the cultural history of the US might think of FM radio as a development of the 1960s, wideband FM radio was actually invented by Edwin Howard Armstrong between 1933 and 1935.

By the 1930's, The Radio Corporation of America (RCA) was the owner of the radio network NBC, and NBC owned about 30 AM radio stations. AM radio was highly vulnerable to electrical noise, both from lightning and from manmade sources – electric motors, automobile ignitions and the like. David Sarnoff, the president of RCA, asked Armstrong to develop a radio system that would not be affected by electrical noise and Armstrong set to work. His solution was FM radio of a type that has now been in use since he invented it almost 90 years ago – wideband FM. This is a form of radio modulation which is impervious to electrical noise and a number of other problems.

Sarnoff was not happy. FM uses a different method of modulation (Frequency, rather than Amplitude Modulation) and is broadcast on different radio frequencies than AM radio in order to produce noiseless higher fidelity sound than AM. Of course all of NBC's existing radio stations were AM stations. NBC's investments in AM, in the midst of the Great Depression, would be seriously impacted.

Armstrong's industry-changing, you might say world-changing, invention would be used sparingly through the 1930's since there was no funding for its expansion. NBC certainly wouldn't do it! We have some samples here in Area 8 of Armstrong FM receivers using the 42 to 50 Megacycle band (as it was called at the time, now MegaHertz), and also of converters that owners of AM radios could connect to their AM radios to add FM capability.

FM radio broadcasting was further threatened in 1946 when the 42 – 50MHz allocation was taken away for the developing Television Industry (for Television Channel 1, although we cannot find any evidence that Channel 1 was ever used. In fact, it was abandoned in 1948). FM was assigned to 88 - 108MHz instead. Any of the early sets and converters thus became useless. With public demand and the growth of high-fidelity audio systems and the development of FM stereo multiplex, FM finally became wildly successful and a dominant force in broadcasting after the late 1950's.

# Section 2 – Descriptions of Display Areas

When WW2 came in the 1940's, use of FM technology in military equipment gave US forces significant advantages. For example in tanks, where US tankers could use their FM radios while in battle. German tanks on the other hand, had to shut down their engines to use their radios since the tank engines interfered with communications similar to the way that early 'spark' transmitters had done in the 1900 to 1920 era (Area 2 of RTM). Some of this story of FM's success is told in the *WW2 Communications Museum* in hallway 9032C.

## Area 9 - Shortwave Radio Technology

The ionosphere of the earth consists of multiple layers of ionized gases at from 40 to 200 miles above the earth, and the lowest layer (D layer) dissipates and recombines predictably with the daily changes in sunlight. This is far above any visible clouds, and so is not affected by cloud layers.

AM broadcast radio operates in the medium wave band (below 3 MHz). During the daytime, these signals travel by groundwaves, essentially 'crawling' along the curvature of the earth for a limited distance. At night and ***if*** conditions are right, the skywaves may reflect off the ionosphere (think of it like a mirror) and appear at some much longer distance from the transmitter, resulting in the DX reception we experience at night.

Short waves (3 to 30 MHZ) always travel by skywaves and **depending on the frequency of the signal**, can be reflected back to certain locations on the earth. When the effective height of the various reflective layers of the ionosphere change (since they change with the day/night cycle of sunlight over each part of the earth as it rotates), the signal will be reflected back to locations on the earth far from the sending location. Since the height of the upper ionosphere is relatively stable, these reflections will come back to earth at predictable distances from the transmitter. This idea of predictability means that **long-distance** shortwave transmissions in any **particular frequency band** can usually be received at some **particular parts of earth** at a **specific time period during each day.** (Remember that when it's daytime 'here' it's nighttime somewhere else).

What does this mean to a listener? The listener can generally receive long distance shortwave signals in the (local) morning at about 11 MHz, and in the late evening at about 18 MHz. This is not totally reliable because it is affected by both long -term effects such as the 11 year sunspot cycle, and short-term effects such as solar flares, temperature inversions, weather conditions and sporadic E-layer skip.

This word picture is more easily visualized by looking at the large illustration seen on the upper wall in Area 9. Also shown in Area 9 are a variety of shortwave receivers, such as amateur (Ham) receivers and military receivers. (When looking at these, don't forget that the multiband receivers shown in Area 6 also include short-wave bands.)

# Section 2 – Descriptions of Display Areas

# The Technology Explosion Begins

## Area 10 – From Transistors on Down - The New Electronics

Areas 1 to 9 of the RTM have shown that the Communications technologies and many other things that make a modern world, (whatever 'modern' meant at a particular time), are dependent on Electronics. This began in the 1920's, but accelerated exponentially because of the invention of one device – the transistor

In June of 1948, Bell Laboratories announced the invention by three of their scientists: *John Bardeen*, *William Brattain* and their Supervisor, *William Shockley,* of a tiny and very fragile device called the **Transistor**. Made of Germanium, it was specifically a 'point-contact transistor'. It had first been demonstrated internally at Bell Labs in December, 1947.

What are some of the reasons that the transistor was developed?
First, the overall goal was to make a better device that could replace vacuum tubes in all or most electronics.

And why could the transistor be better?

**1) size** – transistors are significantly smaller than vacuum tubes.
**2) power consumption** – transistors do not require a hot filament to produce electrons – heating a filament takes a lot of power which is mostly wasted.
**3) heat** – as the previous item stated, a lot of waste heat is produced by vacuum tubes and it must be removed somehow, but most of the power consumed by a transistor goes into its operation and is therefore not excess, but useful.
**4) switching** – an added bonus is that transistors can act as switches as well as amplifiers and oscillators, etc. This became very important with the rise of computers.

Seldom mentioned today is that in June 1948, William Shockley filed for a patent for a device called a 'bipolar junction transistor'. This device was first prototyped in 1949 using Germanium, and with improvements: using Silicon rather than Germanium, and being built by a process called "Grown Junction",

it was announced by Bell Labs in 1951. The Junction Transistor is far more robust and simpler to manufacture than the point-contact transistor. The Junction Transistor is the component that was the foundation of electronics and the electronics industry.

This Area displays some of the artifacts of the New Electronics that are based on transistors. You will see such items as a Bell Labs replica of the first point-contact transistor. Here is the first commercially available broadcast radio receiver – the Regency TR-1 – which was introduced in December of 1954, just in time for Christmas. This was followed by a range of what were called 'transistor radios' or even just 'transistors', by the public. Compare these with the Portable Radios displayed in Area 7. Finally, there is a range of novelty radios. Radios built in the shapes and sizes of other things – pianos, oranges, and even Oscar the Grouch. Why? Because with transistors they are small and relatively cheap – even cheap enough to actually be sold or given away as advertising items. Note the Gasoline Pump.

What have we missed in this display area? The next major – **REALLY MAJOR** – change in electronics. The **Integrated Circuit**, often referred to as a microchip. How do you tell the story of a device so small you need a microscope to really see it?

The integrated circuit idea was developed in the late 1950's by a number of people, notably Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor. What is it? Since transistors were replacing vacuum tubes, almost all of the functions needed to produce electronic devices – transistors, resistors, capacitors - could be put on one piece of semiconductor material such as silicon, and over time each device could be made smaller – and smaller – and smaller. In 1965 Gordon Moore stated what has come to be known as Moore's law[1]: that the number of transistors on an integrated circuit doubles approximately every 2 years.

To provide some idea of what this means, there have been 29 2-year intervals since 1965. By Moore's law, the space taken up by 1 transistor in 1965 would accommodate 500 million in 2024. Another way to look at it: an average smartphone today contains over 10 Billion (with a B) transistors in its

[1] This is not really a "law" of course, but it's his observation based on projections from historical data.

processor. This does not include the number in the phone's memory, which may be over 100 Billion.

In this Area, we show a chart to provide an understanding of what Moore's law has meant to the new Electronics, and by extension, to communications. We do show a few integrated circuit chips – the Pentium computer chip from about the year 2000 shown here, contained about 10 million transistors which is indicative of what was possible over 2 decades ago. But to get a real feel of what the New Electronics means, look at your cellphone!

# Section 2 – Descriptions of Display Areas

## Area 11 - Digital Audio – What, Why and How

What is sound? It is just vibrations, or waves, that travel through the air. If those vibrations reach your ear, the eardrum is vibrated by the sound and the ear converts the sound into something that we 'hear'.

When we hear sounds, they often last for some period of time, and during that time the sound can get louder or softer, and it can change pitch, or frequency. In fact most sounds consist of a complex mixture of many frequencies simultaneously. A few people can hear a range of frequencies from about 20 Hz to 20,000 Hz, most others are more limited.

Where does technology enter the picture? For thousands of years, people have always heard sounds, and then they were gone. Forever. And those people had to be near where the sound was made. Too far away? They could not hear it.

So what might you ask a technology to do? Three things: 1) Record the sound. 2) Play it back on demand. 3) Transmit the sound to another location.

*Record*, *Reproduce* and *Transmit*. The technologies of the last 200 years have delivered on these requirements, and you will see such technologies in another area of this museum. These older technologies, where the sound is directly converted into a form that is an approximate copy – an *analog* – of the sound itself, seem to have served us well. So what is the reason for *digital* audio?

### Issues with Analog Audio

In analog audio recording or transmission, the recording or transmitting system directly copies the loudness and frequency of the sound as precisely as possible, second-by-second. Sound recorded as an analog signal and played back is subject to a number of factors which affect its quality, longevity, economy and convenience. It is highly dependent on the quality of the medium, for example vinyl records or magnetic tape, on which it will be stored. Each of these can be inadequate or can be damaged in numerous ways. Frequency response and dynamic range (loudness and softness) on a physical medium such as vinyl (or the shellac used for earlier records) is limited by the ability of the recording stylus to cut the groove rapidly and widely enough, the mass of the pickup cartridge, and the profile of the stylus.

The surface of a vinyl recording can later be *scratched* across the grooves, *gouged* along the grooves by the playback stylus, *affected by chemicals* on the surface, *overheated* and more. If damaged, there is no way to fully recover the contents.

Magnetic tape is susceptible to stray magnetic fields which could modify the contents, it could be mechanically distorted (pulled, twisted, etc.) or overheated and wrinkled, and it can break.

As to economy and convenience, either of these types of media hold a very limited amount of material. Typical records hold only 3 minutes (45 rpm) or 24 minutes (33rpm) of audio per side. A magnetic tape is limited by the thickness of the tape and the speed at which the tape passes over the record/playback head. High speeds could provide better quality audio, but most consumer-grade tape is limited to 7 ½ inches per second (ips) and audio tape is susceptible to magnetic tape hiss at low speeds. Even with effective noise-reduction techniques (Dolby), compact tape cassettes that run at 1 $^{7}/_{8}$ ips hold about 30 minutes per side.

## Advantages of Digital Audio

In digital audio recording, the sound is not copied directly. Rather, the recording system takes periodic samples of the audio waveform and measures a value that is the amplitude of the sample at each point. These numbers are the 'digits' in *digital.* There is a mathematical theorem often called the Nyquist sampling theorem[2] (named for Harry Nyquist of Bell Laboratories) which has been proven by nearly a century of practical use in both audio and video applications. To paraphrase this theorem, sampling at a rate (samples per second) of ***twice the highest frequency*** in the signal, and passing the sample values through an appropriate low-pass filter, produces a signal that *reproduces completely* ***all frequencies*** *at and below the highest frequency*. In other words, to reproduce a signal of 20,000 Hz, a sample rate of 40,000 samples per second or more is required.

[2] Harry Nyquist's work was published in the 1920's. Other instances of similar work after and even before that are sometimes cited. The theorem is sometimes even called the Nyquist - Shannon theorem, for Claude Shannon (also of Bell Labs) who developed Information Theory in the 1940's.

A well-known practical example is the 40 year old technology of the CD, which uses a sample rate of 44,100 samples per second, easily reproducing sound up to 22,000 Hz.

But in this age of the 'New Electronics' described in Area 10, use of digital recording or digital transmission provides far more benefits than just the ability to reproduce or transmit sounds each and every time this is done. Here are just some of the advantages of digital audio:

**Always precisely reproducible** - in other words the digits are checked each time they are reproduced or transmitted

**Error Correction** – Errors can be corrected before being used, so that except for catastrophic instances such as near-destruction of the medium, the digits are recoverable to be exactly what was recorded

**Easily Editable** - since they are just numbers, the digits can be easily edited by computer apps, for tasks such as reducing noise, removing artifacts such as clicks, combining multiple tracks, etc.

**Compressible** – audio samples may contain strings of digital samples that are repetitive, so the signals are able to be highly compressed and a million bits of data may be compressed into less than half of that.

**Highly Suited to New Electronics –** e.g., since transistors can do switching, they can operate very efficiently on digits. Since integrated circuits can be manufactured with error control capability on-board so to speak, manufacturing need not be absolutely 100 percent error free because digital error correction can be performed in operation.

**Storage and Retrieval of Digits is Extremely Efficient –** Devices using transistors can be made highly compact – some devices can be made that contain Billions of 'digits'. ("Giga-" means Billion).

**Reducing the Amount of Storage Needed -** By a combination of efficient storage and effective compression of the information, Instead of storing 22 minutes of music on a record, you can store perhaps 2 WEEKS of digital audio on a modern device. And considering Moore's Law, this number becomes even higher as devices become even more compact.

In this Area of the museum, the visitors will see some historical devices and technologies such as CDs, CD Players, and a range of Digital Audio Storage and Playback devices such as IPods and other mp3[3] players. They will also have the opportunity to do some editing of digital audio on a computer using a digital

[3] mp3 stands for the data compression standards that are used for most digital audio. "mp" is short for the industry's "Motion Pictures Experts Group" (mpeg) which developed these standards.

audio editor. They will also learn more about the significant features of digital audio.

## Area 12 - Television – Introduction and Development

The earliest experimental televisions were mechanical systems that used a single light sensitive device behind a spinning disk with a spiral of holes in its surface. Some of the experimenters in the 1920's and 1930's were Charles Jenkins in the US, and John Logie Baird in Great Britain. Baird's version actually went into service in England in 1932, while Jenkins' system in the US was only experimental. We only have the box of a Jenkins system and it is not on display.

RCA, under David Sarnoff and using Vladimir Zworykin's CRT display, wanted to deploy all-electronic television and spent many years (and dollars) in its development. At the New York World's Fair in 1939, Sarnoff introduced electronic television to the world, RCA deployed a number of television stations and began offering TV sets for sale to the public. Unfortunately, the time was not right. He announced it on April 20, 1939, and World War 2 began in Europe 4 months later, on September 3, 1939. Broadcast Television had to wait until after the war – until 1946.

Following the war, RCA could finally introduce and sell television and television sets, using the improvements that had been developed during the intervening years. They introduced the RCA 630TS, a newly developed 10 inch set originally priced at $435, later reduced to $350 ($5600 in 2024 dollars).

This area of the RTM displays some of the sets from about 1946 to 1951. CRT design was not very advanced at this time, screens were small – 10 inches was typical. As a result, a number of different methods of increasing the size of the image were tried.

Specifically, there is a 10 inch RCA TS830 (a direct descendant and very similar in design to the 630TS). A magnifier is placed in front of its screen but can be moved for comparison if you wish.

There is also an RCA 648PV rear-projection television which displays a much larger image. However, you will notice that vintage projection TVs such as this are very dim, and sometimes have focusing issues as well. Also, they were very expensive. This one would have been $14000 in 2024 dollars. Of course, it does include a record player and an AM radio - and a nice cabinet - as well. Supposedly David Sarnoff, the chairman of RCA, had a 648PV like this in his New York apartment.

There is also an Admiral 14 inch television of vintage 1951 displayed. By the 1950's, these kinds of sets from a wide variety of manufacturers were available. There is a chart here from RETMA data (Radio and Television Manufacturer's Association) that shows how fast television grew – from 44000 sets in the entire US in 1946, to 24 million in 1952.

Some of the television programs that were popular in the 1950's and 60's can be seen on these TVs.

Transistors had just been invented and would take years to appear in TVs, so television sets of this era used vacuum tubes only - and lots of them – the TS830 for example had 30. A typical TV might break down multiple times a year, and the problem was often a failed vacuum tube. At first the solution was to call a repairman to your house. By the 1950's and 60's, self-service tube testers such as that on display here began to appear in drugstores, hardware stores and many other locations. TV owners could remove tubes from their sets ***(SHOCKING!)*** , take them to a local store, test them, and hopefully purchase a replacement for a bad tube.

The cabinet to the left is also part of the TV Area. Various types of video camera tubes are on display – iconoscopes, image orthicons, and also solid-state devices such as CCDs. Early TV remote controls and a number of other TV-related devices are also shown.

A related television display is shown near Area 11. It is a vintage 1948 Television Camera and a standard 1950's black and white television set. Visitors in the field of view of the camera may view themselves on the black and white TV screen. Note that this is a simulation to provide visitors with the look and feel of TV broadcasting. The camera we actually use is the tiny CCD camera with the red light, and the display is a flat-screen LCD display.

## Area 13 - Telephones – Electrical to Electronic, Wires to Radio

This museum is about technologies that provide communication. Since the emphasis is on RADIO communication, what is probably the most ubiquitous form of radio in the world? Here is a hint. There are nearly 6 Billion cellphones in the world today, and 7 Billion people.

But the world of person to person electrical communication did not begin in 1983, when cellular service was introduced in the US, or even in 1948 when commercial Mobile Phone Service was offered. The cellphone is a result of a confluence of many technologies, but surely one of the major ones is the telephone – the wired telephone.

This Area of the museum demonstrates the straight line of ascent from Alexander Graham Bell's (or Elisha Grey's) invention of the telephone in 1876 through many intervening developments and changes, to today's wireless world.

Once the telephone worked between 2 people, a "central" office had to be developed where the wires of all telephone users came, and where an "operator" could connect them together 2 by 2. Soon (by the 1880's) some of the Central Offices in cities became very large. And some in small towns remained small, but every one needed at least 1 operator. In 1890, a telephone subscriber and small business owner in one of those towns named Almon Strowger solved a problem by inventing a device called a step-by-step (SxS) switch. In this Area of the museum, we display a working SxS switch and you can read about Strowger's problem and solution there. Admittedly, the SxS switch shown here is a much later version (probably from the 1950's) of Strowger's switch. Since the 1890's many other types of "switching systems" have been developed over the years with names like Crossbar and Panel, and including a number of Electronic Switching Systems (ESS), which are essentially computers. However, SxS remained in use somewhere until about the 1980's.

Telephone use expanded tremendously in the century after 1880, and the 'network' between the Central Offices changed. It changed from individual pairs of wires to cables with "carrier systems" which were essentially radio-like systems (and there were also real microwave radio systems as well), and instead of carrying 1 conversation, could carry hundreds to thousands. During this time, the telephones themselves remained straightforward devices that Bell himself could easily have recognized and explained. In this Area we display

a number of different historic telephones, many are labelled for their historic provenance, and many of them work – connecting to one another as they always did, and some have limited connections to the rest of the world of telephones outside the museum (By choice, we only have 1 line to the outside world).

But then came the big change. People had always envisioned being able to have a telephone you could take and use anywhere (except of course for nuisance calls, or having your boss call you on the weekend – didn't want those!). Telephones that could be used wirelessly. As early as 1907, Lee DeForest among others suggested how this could be done. We have a cartoon hanging in the museum that was in a London (England) newspaper in 1923 that points out some of the problems of a "pocket telephone". There were a few 2-way mobile radio carphones as early as 1933 (Bayonne, NJ police).

In 1948, AT&T offered the first public radio carphones that could connect to the telephone network in the US. The problem was that a carphone itself could only connect to one location which then connected to the telephone network. Also, the number of radio channels the carphone could connect to in any city were very limited. If there were more than a few carphones trying to call, only a VERY few could be connected. For example, in the entire city of St Louis, only 3 mobile callers could be connected at any one time.

Technical companies including Motorola and Bell Labs were working on the issue. In the museum, we have a copy of a memorandum at Bell Labs by Douglas Ring in which he analyzes and proposes a system that would use a collection of *cells* independent of one another, and therefore a much larger number of users could connect at a time. The FCC also allocated many more radio channels. The problem? It would take significant advances in many different technologies to make this possible: in computers, in miniaturization, in telephone switching, in FM radio technology and numerous others. But these were FAR in the future. So how far? This memo was written in December 1947, and the first commercial cellphone service in the US was in September 1983.

# And Before all of this, There Was …

## Area 14 - Origins – The Scientific Revolution

(We will create text for this section – it is in transition right now.)

# Section 2 – Descriptions of Display Areas

## Area 15 - Audio History Before the Digital Age

This area displays acoustic sound reproducing equipment, beginning with the earliest phonographs that accommodate cylinders and flat discs (the word "record" is unfamiliar to some of our younger visitors). The display then shows examples of electrified phonographs that were designed to handle the latest in record improvements (45rpm, 33rpm so-called "microgroove" records). Other means of recording and playback are also on display such as magnetic wire recording, magnetic tape recording, 8-track tape, cassette tape, and CDs. Audio improvements such as High Fidelity and Stereo are also covered by a display of hi-fi components. For many of our visitors, the operating jukebox and diner booth (no food, but good music) sparks instant recognition.

---

This Area of the museum displays many of the methods of mechanical and electronic recording and reproduction of sound before the advance to digital audio based on the principles of Harry Nyquist and especially Claude Shannon, developer of the idea of Information Theory.

The era of sound recording and playback began in the late 1800's, long before the beginnings of broadcast radio in 1920. In fact, recorded music was already a big business by 1910, and many homes had record players similar to the early Edison and "Victrola" players displayed here.

In 1860 a French inventor, Edouard-Leon Scott de Martinville, made some of the first sound recordings known. He built a sound recorder, but had no way of playing back the sounds he had recorded. In 2012 The Lawrence Livermore Lab in Berkeley California, using computer-based analysis, has recovered some of the sound from one of de Martinville's recordings. However, the first recording and playback with recognizable sound, was made at Thomas Edison's laboratory in Menlo Park, New Jersey in 1877. Edison's efforts became the famous Edison Cylinder Player, one of which is displayed here.

Other mechanical players also displayed here. The familiar flat disk made out of hardened shellac had been invented by Emile Berliner, and was much easier to produce in quantity than the cylinders used in Edison's machines. There is a Victrola here to play those 78 rpm disks. The name Victrola is reserved for

players built by the Victor Company of Camden, NJ. There is an early gramophone, also to play the flat 78 rpm disks. The unit displayed here was built by a manufacturer other than Victor, and hence the more generic name, “gramophone”. Finally, there is an Edison *disk* player. After the gramophone became popular, Edison designed and built disk players as well. Edison disk players

The next notable step were electronically amplified record players with an electric motor spinning the turntable. We have one that plays 78 rpm records, but also ones that play the 45 rpm vinyl records that were introduced after World War 2.

Another approach was the recording and playback by magnetic means on either a thin iron wire or on a ferrite-coated plastic tape. operating magnetic Wire Recorder. Beyond that, we also display systems where the magnetic tape is wound into various types of cassettes – common cassette systems, 4-track and 8-track systems and

We also display an operating AMI Jukebox from the 1950s. This mechanical marvel (which does NOT require coins – it’s free) is a delight to watch while it operates.

A Diner Booth with an operating Seeburg  Wallbox from the early 1960’s is very popular with visitors. They may sit in the booth, and may choose any of 200 songs. This is also free – (first press the large round black button on top). **DOCENTS ONLY** - *there is a small volume control of the top of the wall, at the back of the booth. There is also a square black cancel button on the vertical surface at the back of the wall .*

# Try it Out

## Area 16 - Hands-on Room – for Kids of All Ages

The “hands on” room is a space where visitors may try out various technologies, from static electricity generation to crystal radio sets to a “hand battery” to a Jacob’s ladder. There are audio experiments, and Plasma balls. There are a variety of magnets, generators and other objects, and also a Tesla Coil which the Docent may demonstrate. For safety reasons, PLEASE DO NOT LET VISITORS TURN ON THE TESLA COIL. The Tesla Coil has a locking key switch, the key is kept in the locked cabinet on the wall behind the coil. It is for YOUR USE ONLY. Be careful NOT TO LEAVE THE KEY IN THE SWITCH when you leave this area.

## 1. Miscellaneous

*THIS PART OF THE WRITEUP WILL BE UPDATED*

This is an area of the museum where we display a number of different interesting, but different technologies. Loudspeakers, telegraph keys, microphones, and a number of other interesting radios from the 1920's and 1930's that don't quite fit elsewhere.