Volume 43, Number 1

Spring/Summer 2024

Journal of the

# CALIFORNIA HISTORICAL RADIO SOCIETY


FOR THE RESTORATION AND PRESERVATION OF EARLY RADIO

FROM THE BIRTHPLACE OF BROADCASTING

# CALIFORNIA HISTORICAL RADIO SOCIETY

HOME OF THE BAY AREA RADIO MUSEUM & HALL OF FAME

The California Historical Radio Society (CHRS) is a non-profit educational corporation chartered in the State of California. Formed in 1974, CHRS promotes the restoration and preservation of early radio and broadcasting. Our goal is to enable the exchange of information on the history of radio, particularly in the West, with emphasis on collecting, preserving, and displaying early equipment, literature, and programs. Yearly membership is $40 ($50 non USA).

## CHRS Museum in Alameda

CHRS has been fortunate, through the generosity of its donors, to purchase a home for the CHRS museum and education center. It is located at 2152 Central Avenue. The building was built in 1900 as a telephone exchange.

CHRS volunteers are actively restoring the building to make it optimal for use. Our goal is to create an environment to share our knowledge and love of radio and enable us to create an appreciation and understanding for a new generation of antique radio collectors and historians.

Please come visit us any Saturday 9am to 3pm. Visitors and groups welcome at other times by appointment; Contact Steve Kushman.

◊


**Contact us:**

CHRS, PO Box 31659, San Francisco, CA 94131
or info@californiahistoricalradio.com

**Visit us at:** www.CaliforniaHistoricalRadio.com

# Contents of the Journal



**Front Cover: From Radio News, May 1926.**

**Rear Cover: Images of the CHRS Holiday Luncheon**

## From the Editor

I wish to again thank John Okolowicz for a most interesting story of product promotion and radio. I authored two articles this time. The first is a saga of forecasting technology and predicting the future in 1926, and a look at how that turned out. Second, I continue from my earlier article "The Enigma of Ultra", this time discussing the decryption of radio teleprinter communications during WWII. Philip Monego, Rachel Lee, and Steve Kushman provide updates. Eddie Steeves gives us an update of the Central Valley Chapter.

I am always in need of quality content related to broadcast radio, ham radio, and television. If you have something to contribute, I urge you to let me know. I am especially interested in technical content. It can be of two types, a narrow topic in depth or a more broad topic with less depth. Enjoy . . .

Richard Watts, jrchrs@comcast.net

◊

## From The Chairman

by Philip Monego

Philip at the CHRS Holiday Luncheon.

I am pleased to have assumed the chairman role with the support of Mike Adams and the board.

What does that mean? Where are we and Where are we going?

For those that don't know me; a few background comments…

I started early to have an interest in radio. My father was a ham and a radio guy and had me working on pulling out parts of junk radios and TV's in grammar school. Became a ham myself in high school, got my first job as an electronics technician aligning R-390 receivers for Electronic Assistance Corporation (EAC). Then went to work as a tech for Electronic Associates Incorporated (EAI) working on vacuum tube analog computers and eventually automated drafting equipment. Took some college at night but kept on full time work. Over my career I focused on smaller technology companies and eventually startups which led me into Interim Executive Management consulting as CEO and Chairman for more than a dozen companies. Work was great and I learned a lot, but there wasn't time for radios.

I got back into my dormant radio interest when I was introduced to CHRS almost 20 years ago. Retirement soon thereafter allowed me spend the time collecting and restoring what became a fairly large collection of mostly pre-war Zenith radios. CHRS rekindled the interest which continues today.

While we ready ourselves to celebrate 50 years since our inception, who of our founders would have expected that years later we would own a building, have more members than ever before and be recognized as a leadership organization within the local radio and broadcast community

While we are currently a financially strong 501©3 Non-profit company thanks to our generous donors, unlike other non-profits we have not yet reached out beyond our membership to secure additional financial footing and support. The members have done much, but as we look to the future, how do we best assure that we are relevant and secure?

In 1974 we started out as a "club" of like-minded individuals with a passion for radio; its stories, history and equipment. Most of us were collectors with a common interest. Is that sustainable? I fear not…

Here is a reality that most of us recognize, we are aging out and not enough within our new member community are of that collector mindset. Not to say that the history of broadcast and the technical developments and uses are not of interest to members, they are, but we need to reach beyond. The public needs to be there to support us going forward.

The board has recognized and supported the need to change. We can continue to do what we have so successfully done since we acquired the building, rebuild and restore…. Then what?

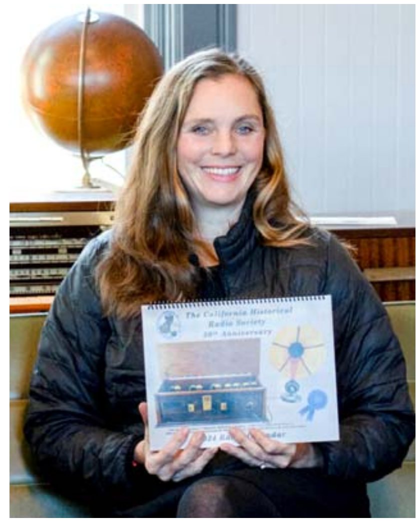
To be perfectly clear, to survive and be relevant we need to embrace the idea of operating much as the way a business does. Have a clearly stated set of objectives, put individuals in place to fill expertise gaps, become relevant to the local community and fund our current and future needs.

The first major step the board took was to ask Rachel Lee to assume the new role of Executive Director. Rachel is the right person to bring operational focus on the future. At the same time, we are recruiting new board members with experience where we fall short — Museum design and operation, Education for membership, community, and school tours and programs, and Fundraising.

Our goal is to open The Wireless Discovery Center to the public in 2024. With dedicated volunteers and your continued support we will hopefully all soon be able to take CHRS to a secure future. ◊

## From The Executive Director

by Rachel Lee



Rachel with the CHRS 2024 Calendar.

As we embark on 2024, the California Historical Radio Society (CHRS) stands at a remarkable crossroads where the rich history of radio intersects with the vibrant potential of the future. Our mission, deeply rooted in celebrating the legacy of radio, has never been more relevant or exciting.

### Embracing Technology and Expanding Reach

The world of radio has always been about connection and community, and CHRS is expanding these core values using technology. You can find our digital archives making our extensive collection of broadcasts, recordings, and radio artifacts accessible. This digital leap is not just about preservation; it's about opening our doors, virtually, to enthusiasts, researchers, and the curious alike, no matter where they are.

### Educational Outreach and Inclusive Programming

Education is a cornerstone of CHRS's mission. In 2024, we are committed to broadening our educational programs, focusing on engaging younger audiences. Our series of workshops, lectures, and seminars aim to ignite a passion for the science and art of radio, fostering new radio enthusiasts and professionals. Additionally, we are collaborating with local schools to integrate broadcast history into their curriculum, bringing a hands-on approach to learning about this influential medium and how it is used in our 1950's broadcast studio.

### Live Events and Community Engagement

The magic of radio was always in its ability to bring people together, and this year, CHRS continues to cultivate this spirit through a variety of live events. From vintage radio repair workshops to guest lectures by notable figures in the industry, we are creating spaces for people to connect, learn, and share their love for radio. Our annual Radio Day by the Bay remains a highlight, promising an exciting lineup of live auctions, demonstrations, and performances that celebrate the golden age of radio. Additionally, with the addition of our amazing volunteer coordinator we can find ways for you to meaningfully engage with CHRS wherever you are. There is something for everyone here and we can only move forward with your help.

### Preservation and Restoration Efforts

Our preservation efforts in 2024 are more ambitious than ever. The CHRS Radio Museum, located in the historic Alameda Telephone Exchange, is not just a repository of artifacts; it is a living, breathing space where restoration and preservation happen in real-time. We are dedicating resources to restore our building to its 1900's glory and to bring historical radios to working condition, allowing visitors to experience the authentic sounds of the past.

### Collaboration and Partnerships

Recognizing the power of collaboration, CHRS is forging new partnerships with like-minded organizations and institutions. These collaborations aim to enhance our collections, expand our reach, and bring diverse perspectives to our programming. We believe that by working together, we can more effectively celebrate the rich tapestry of radio history.

### Moving Forward Together

As we tune into 2024, the California Historical Radio Society is not just looking back at the glory days of radio; we are actively shaping its role in the present and future. We invite you to join us on this exciting journey, whether it's through visiting our museum, participating in our events, or exploring our digital archives. Together, let's keep the spirit of radio alive for generations to come.

◊

## What Is Old Is New Again - CHRS Radio Central Gets A New, (Old), Facade

by Steve Kushman

It's taken a long time to plan, but CHRS is now ready to tackle our biggest and most ambitious project at Radio Central. As shown in the left picture below, our building at 2152 Central Avenue, Alameda, constructed in 1900, was built in the California Mission Revival Style reminiscent of early California architecture as seen in many vintage buildings and the chain of California Missions. It was built as the first telephone exchange in Alameda by the Sunset Telephone and Telegraph Company. As time went on, the phone company, now Pacific Telephone, outgrew this space. So, in the 1940s they built a much larger facility down the street on the corner of Central Avenue and Willow Street. 2152 Central Avenue was then sold to the Church of the Nazarene. In the 1950s, in the name of "modernization", the Church covered the original facade, removed the front stairway, and added a new entrance on the right side of the building.

When CHRS purchased the building in 2014, one of the goals was to restore the original facade. Well, it has taken 10 years of ownership, raising capital and about 11 months to plan and prepare our package of drawings and calculations for permit submission. We have had an outstanding team working on this project. Vincent Wu is our structural engineer, John Stuart is our chief draftsman, Mark Hulbert is our architect, and I am proud to serve as our project manager.

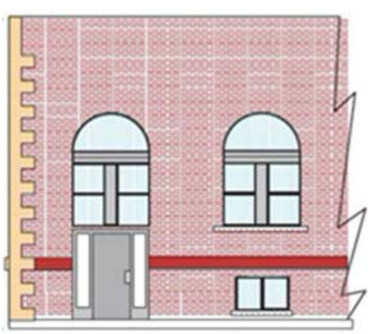

2152 Central Avenue circa 1900 (left), and as it was in 2014 (right).

We did some exploratory investigation behind the false wall of the original structure and surfaces. Based on what we could see, we were pleased to find that some consideration was given to protect the original detail. Well, at this writing we are ready to go! Our plans, calculations and application have been submitted to the City. Once approval is received, our contractor B.A. Morrison & Co. will be ready to go. Mike and his crew have worked with us on the Great Room restoration and our downstairs reconstruction from the flood — each time they have done first-rate work. Below are some of the drawings by John Stuart that are part of our submission. If all goes according to plan, we should see some big changes to Radio Central as we celebrate CHRS' 50th anniversary on July 27th. Please stand by…

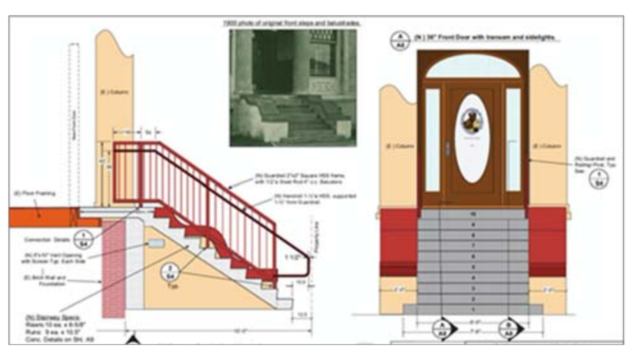
Exploratory holes made to assess the condition of the original facade.

Original woodwork looks pretty good .

Proposed front elevation.



Proposed side entry.



Front entry detail.

◊

## CHRS Central Valley Chapter News

by Eddie Steeves

As CHRS Central Valley Chapter saw a very busy and productive year come to a close, we celebrated Christmas in our traditional fashion with a Christmas lunch at Bella Italia in Modesto. The luncheon was attended by our members and their guests; it was fun and enjoyable. We also presented this year's My Favorite Radio Restoration Contest winner, Edward Steeves, with the award, congratulations Eddie (yes, it was me).

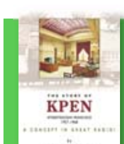
As we rolled into the new year we continued to stay busy and productive in the clubhouse and community. We again attended the Model A swap meet at the Stanislaus County Fair which was very fun and successful.  A big Thank You to all of the members who made it happen including John Wallin, Archie Durham, Jerry Davis, and Joe Holland; and a shout out to Mike Loper and Scott Pierce for staffing the Booth.


CVC My Favorite Radio restoration contest.  Eddie Steeves (right) won with his beautifully restored chairside; Mike Loper (center) was second, also with another very nice chairside; and Scott Pruett (left) was third, with a great looking clock radio.

CVC is looking forward to another busy and fun filled year.

For an update on all our activities, visit CVC at [www.cvantiqueradio.com](http://www.cvantiqueradio.com) . ◊

## CHRS Publications




**The Story of KPEN:  A Concept in Great Radio!** Gary Gielow has written a book chronicling the tales of two young men from Stanford, he and James Gabbert, who brought Stereo and new ideas to the FM radio band in the late 1950s and 1960s.  This book is the definitive history of KPEN 101.3 FM, the 2015 BARHOF Legendary Station.  100% of the proceeds benefit CHRS.  Available in the Museum Store or on the website.

**The Radio Boys And Girls—Radio, Telegraph, Telephone and Wireless Adventures for Juvenile Readers 1890-1945** covers more than 50 volumes of wireless and radio themed fiction, offering a unique perspective on the world presented to young readers of the day. The values, attitudes, culture and technology of a century ago are discussed. Available at Amazon.com



**Behind the Front Panel: The Design and Development of 1920's Radio** by David Rutland has been remastered by Richard Watts for CHRS.  With emphasis on radio technology,  Rutland describes the development of 1920s tubes and radio circuitry designs by De Forest, Marconi, and other inventors and manufacturers.   A classic!     Buy at Amazon.com

**CHRS Journal Special Edition** — **Television** a compilation of original articles on television,  including articles by Malcolm Baird on his famous father, British television pioneer-inventor, John Logie Baird, Don Godfrey's historical bios on CF Jenkins and Philo Farnsworth, plus restoration and technical articles from CHRS members.  Available at Amazon.com


◊

## A 1926 Look Into The Future

By Richard Watts

**"It's tough to make predications, especially about the future."** — Attributed to Yogi Berra and Niels Bohr.

During the 1920s Hugo Gernsback was editor of Radio News magazine. He used this magazine as an opportunity to editorialize his vision and predictions of future developments in radio and television. At this time television, with which he was particularly enamored, was becoming a technical reality. In his editorial for the May, 1926 issue, he focuses on the imminent future of television, which would prove to not be so imminent — he further predicts the availability of a widespread interactive audio/visual communication network via television and telephone. His forecast and predictions would come to pass, but not in the timeframes or forms he imagined. Realizing these outcomes would require several disruptive culture shaping technologies to be developed and adopted. Hugo Gernsback's Radio News editorial follows:

## Radio Television

By HUGO GERNSBACK, F. R. S.

I am frequently asked this question: "What, in your opinion, will be the next great development in Radio?" And to this question I always answer that, in my opinion, the next and most logical step in Radio will be the establishment of "Television," or the power to see objects at any distance, through the same medium by which we are now enabled to hear sounds by radio from all over the world.

Radio receiving sets have been developed to such a high degree that we need not expect any revolutionary improvements to be made in them for some years to come. The radio receiver is now at the stage of development such as the automobile reached ten years ago.

The improvements made since then in the automobile have been only in the refinement of its various parts; and it will prove exactly so with radio.

So, when I speak of Television, I do not predict a novel type of radio set per se, but rather the creation of a device which can be attached to your radio set. It will be similar, in its relation to the present radio set, to the loud speaker, which can be connected to your set, regardless of whether the latter is of the vintage of 1923, or the latest 1926 model.

The cover of the May 1926 issue of Radio News.

This may seem to be a rash, offhand statement, but a moment's consideration will show that it is not. For instance, you can listen to a full orchestra with your radio set and (providing you have good transformers and your loud speaker will take both the upper and lower ranges) you will find no trouble in distinguishing the notes of the bass drum from those of the piccolo, even though both are playing at the same time. In other words, you hear simultaneously a number of different instruments without their interfering with each other.

Through the future application of Television, it is quite logical that while a station is broadcasting a song, you will be able to see the face of the singer at the same time, through a transmission on the same wave to which you are tuned in, for the following simple reason.

The range of acoustical frequencies is really very narrow, and does not take in a wide band; the human ear responds to no vibrations above a frequency of 23,000 per second. That is the reason why the so-called radio "carrier" is inaudible. To the nontechnical reader it may be explained that the "carrier" is the fundamental wave emitted by a broadcast station, which is on the air at all times when the station is transmitting. When no one is speaking or singing at the broadcast studio, you hear nothing but a faint rushing sound in your receiving instrument. The vibrations of this carrier run into millions per second, and that is why we cannot hear them directly.

If however Television is perfected (as it almost surely will be during the next two years, or perhaps sooner) it will be possible to impress the Television impulses upon this same "carrier" which brings the 'sound impulses to your set. The Television impulses, being of a frequency too high to be audible, will not interfere with your loud speaker ; and the Television picture for the same reason, will not be mixed up with the speech, any more than a violin or a piano, both of which you can readily distinguish with your ear. This is an inadequate comparison, because the separation between the acoustical band or audio frequencies and the radio frequency band is enormously wider than that between any two audible notes of music; and it will therefore be practically impossible for the "sight" waves and sound waves to interfere with each other.

I have pointed this out to bring home the point that, when Television is finally brought about, it is quite probable that today's radio sets will be adapted to this new purpose; and that it will be possible to connect a Television attachment right to your present set and thereby see what is going on all over the country while you are enjoying the program. Not only will it be possible to see the entertainers at the broadcast station to which you tune in, but everything that is broadcast for sound only, today, will be broadcast by "remote control" for Television as well.

Radio Television, it must be said, is nearer at hand than most of us realize. The inventors of the entire world are racing frantically for the goal, because they realize that in Television they will have created a great new emancipator, much greater than the telephone or radio communication itself.

In this country C. Francis Jenkins has been in the foreground in Television experiments; and he has achieved success in making it possible to transmit and receive the outlines of moving objects by radio at the present time. In England, it is reported, John L. Baird, who has been on the same track, has accomplished a great deal; in France Professor Edouard Belin has also produced results, and similar work has been done in many other countries. Television is now "in the air," and I shall be very much surprised if this great new art does not step out of the laboratory into every -day use, sometime in the next two years, or less.

Back in 1915, and again in 1918, I wrote a series of articles on Television which were the first, I believe, published in the technical press. At that time we had only the selenium cell as a "photoelectric" or light-sensitive substance; but it is sluggish and does not follow changes of light with sufficient quickness. It has been superseded recently by some very excellent light-sensitive cells, which react to changes in less than one ten-thousandth of a second; and this improvement makes Television an assured possibility today.

We should not be surprised, also, when the final apparatus is evolved, to note with what simple instruments Television can be accomplished. It is my belief that the successful device will be simpler and of fewer parts than our radio receivers are today, and it is quite possible that within the next ten years $50 will purchase a complete Television attachment which will perform well.

To be sure, for a long time to come, transmission will be only in black and white, giving an effect similar to that seen in motion pictures now. Color transmission will come later.

At this point I desire also to correct an erroneous idea about Television, which is much in vogue now. Many people think of Television as "radio motion pictures." Of course there will be no motion picture equipment of any kind in the radio Television apparatus. Television does not concern itself with such methods at all. In reality von will see at a distance, just as if you had a telescope through which you could observe anything going on in any part of the country.

Television between broadcast stations and the broadcast public will become very popular. If the telephone companies wish, they can make simple attachments for the present-day telephone, so that you can see the person at the other end with whom you are conversing.

A lot of people will throw up their hands in horror at this idea, because the idea of Television added to the telephone will suggest a reduction of their privacy to the minimum enjoyed by a gold fish. This need not be feared, however, because a pushbutton in the telephone mounting will insure that the party calling cannot see you unless you wish it. This is a very simple detail.

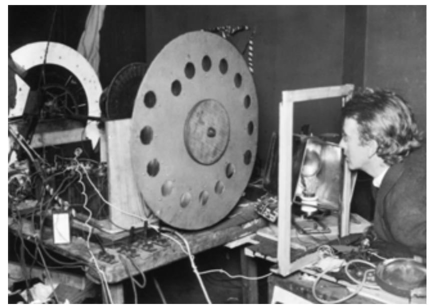
As to radio Television between private parties, such as depicted on the front cover of this magazine, I must admit that this lies much further in the future, perhaps twenty-five years or more, for there are not enough wave-bands available to make it possible for thousands to talk to each other at the same time. On the other hand, the cover illustration could readily represent two radio amateurs, who can converse by radio telephone even today; and if, in the next two years, they are enabled to place Television attachments on their radio sets, there might easily result such a situation as shown on the cover. But the individual application of Television, to every one's personal convenience, will not be practicable for many more years.

---

Hugo Gernsback forecast that television was perfected and its adoption was just around the corner. So what was the state of television technology in 1926 that was the basis for his optimism?

## Television

Television in the 1920s was experimental. In England in 1923, John Logie Baird developed a mechanical televisor based on using the spinning disk mechanism proposed by Paul Nipkow in 1884. By the early 1920s, the Nipkow approach was finally viable due to the availability of vacuum tubes for signal amplification and photocells for image capture. The BBC broadcast regularly scheduled 30-line television programs beginning in September, 1929.



John Logie Baird's televisor scanner, 1925.

A televisor image.

In the mid 1920s, U.S. inventors including Charles Francis Jenkins in Washington D.C. and Ulises Sanabria in Chicago, working independently of each other, were also experimenting with spinning disk approaches. In 1928 Charles Jenkins started the American Television Corp. and a broadcast station W3XK in the Washington D.C. area.

Western Television Visionette on display and working at CHRS.

In 1929, Mr. Sanabria and his team were working as Western Television Corp. By 1929, they produced televisions with an interlaced-line disk design. In 1928, Mr. Sanabria also built and operated a television station W9XAA which later in 1929 became W9XAO. The sets were intended for experimental purposes. It is estimated Western sold only a few hundred sets. One of these devices is on display at CHRS in the Television Exhibit area.

Picture quality was very poor, typically 30-lines of vertical resolution with a picture size of 1-2 inches in height and width. The frame rate was slow enough, the images likely had a noticeable flicker. Television signals were broadcast initially on the AM band, later the shortwave band was used to enable somewhat higher resolution (45-60 lines).

In the U.S., by 1931, there were about 25 television stations. Because of the poor picture quality, mechanical television was not a success. Economic conditions resulting from the Great Depression of 1929 most certainly contributed to the lackluster interest and sales of television by the public-at-large given the high price tag and poor picture quality. By 1933, in the U.S. almost all televised broadcasting had ceased and, in 1936, the 2 MHz television band was reassigned for police use. BBC mechanical television transmission continued until 1935 when it was replaced by electronics systems.

A televised telephone call occurred in 1927 between the Commerce Secretary Herbert Hoover in Washington D.C. to an audience in New York City via a telephone link. Gernsback must have been encouraged that a telephone link was used and the audio portion was interactive two-way, but the visual portion was only one-way.

Herbert Hoover televised in 1927 from Washington D.C.

Television was clearly in its infancy, but in 1926 Gernsback must have felt enough technological progress had been made to suggest mainstream public adoption of television could be just around the corner a few years away. In hindsight, television technology at that time was not much more than a curiosity. The technology would have to evolve much further to improve signal resolution needed to enable an acceptable higher quality image that the public would be more apt to readily accept. Further, the industry would have to mature and cooperatively build an infrastructure based on signal format standards, transmission frequency allocations, and broadcast practices before television could be widespread.

The evolution of technology took a big step forward with the move to electronic television in the 1930s, primarily through the inventions made independently by Philo Farnsworth and Vladimir Zworkyin. The approach centered on the use of the cathode ray tube for image display plus the Farnsworth Image Dissector for image capture. David Sarnoff, head of RCA, which had a dominant position in radio, believed RCA should dominate television as well. In 1929 Zworkyin, who was working for General Electric, met with and convinced Sarnoff that the electronic approach was superior to mechanical, which Sarnoff then supported.

Development time was needed for the electronic system to be perfected, so from the early 1930s RCA actively worked against the progress of mechanical television by buying patents and buying out small mechanical television companies. Also from the early 1930s, there were demonstrations of electronic television by Farnsworth and also by Zworkyin showing the industry, press, and public of things to come. During the 1930s, the patent and license litigation between Farnsworth and RCA was the stuff of legend ending in September 1939 with RCA having to pay licensing fees to Farnsworth of $1M over ten years. With that, RCA then had the television industry dominance it fought for. RCA demonstrated electronic television products to the public at the 1939 World's Fair.

1939 RCA TT-5 pre WW2 television connected to a radio for the audio portion of the program. Source: Nat Pendleton.

By 1939, the technology had evolved to enable receivers to have an acceptable image and performance to make it a viable product for the consuming public. Yet, adoption still required industry-wide standards for compatibility of competing products, and market momentum to sustain the sales growth that an industry requires to move from prototype to profitability.

Industry-wide standards were the providence of the Federal Communications Commission (FCC). The FCC formed the National Television Systems Committee (NTSC) in 1940 made up of technology experts and industry representatives to determine and draft the television signal format standards and frequency band requirements for television transmission and reception. The FCC approved and published NTSC standard in 1941. Included in the standard was the elimination of channel 1 from the VHF dial. Only VHF channels 2-13 and eventually channels in the UHF band would be used in the future.

Sales growth and market penetration was a chicken and egg affair. Receiver sales depended on the availability of desirable programs to watch, which depended on having an audience large enough to justify programming and studio expense — round and round. In the first few years, television sales were mostly in large cities on the East Coast and around Chicago. The few stations in each market, were only on a limited time each day with very limited programing. Sports was a big attraction, so some of the early TVs sales were to bars and pubs intended to entice the locals to come and have a drink and watch a game. Growth was curtailed during the war years 1941-1945 and television manufacturers were diverted to the production of wartime devices (radar, etc.). The business restarted in 1946.

In 1950, the NTSC would meet a second time to work out the standards of color television and resolve the competing proposals from RCA and CBS, each having very different approaches which were incompatible with each other. Further, the CBS proposal was incompatible with the then current black-and-white transmission standards which would have resulted in the obsolescence of all existing television receivers that had been sold to that point. The CBS proposal was rejected and the RCA approach was approved in December 1953. NTSC would be the standard until 2009 when it was formally replaced with the Advanced Television Standard Committee (ATSC) which defined digital television.

National radio networks soon added television capability and over several years implemented cabling between network outlets so that programming could be available nationwide in near real time. One could safely say that by the end of the

1950s, television had finally arrived as Gernsback had forecast. Television had become pervasive and was shaping cultural dynamics with market share sufficient to supplant radio as the primary platform for media and entertainment. For more information about the history and evolution of television, see the *CHRS Journal Special Edition — Television*.

Gernsback also predicted in the future, perhaps within 25 years, of a two-way auditory/visual communication network that would enable interaction at a distance, a network where one could even interactively propose marriage remotely. Gernsback suggested its implementation in terms of technologies familiar to him, that is telephone, radio, and television. Realizing that prediction is a most interesting saga. Let's take a look.

A 1949 General Electric 800. television. Author's collection.

## ATT Picturephone

Gernsback's prediction was almost realized when, in 1964, ATT Bell Lab's introduced the video-calling Picturephone at the World's Fair, which was connected with another Picturephone at Disneyland in California. ATT revised the product in the late 1960s and marketed it until the mid 1970s. The product was very expensive, had abysmal sales, and ultimately was a commercial flop. From *Today's Engineer*, *Feb. 2014*, "A new technology needs some niche group of enthusiasts to sustain it over the early years; and the Picturephone did not find such a group. The second was cost—it proved more expensive than its value even to the targeted business markets. Most new technologies are expensive at first but then come down in price. AT&T was confident that costs would come down over time, in this case with the coming employment of digital technologies, but Picturephone did not last that long. Finally, most of those few customers that it had didn't like the service. It turns out that most users, even in a business setting, simply did not like being routinely seen on the telephone, or at best found it added little value." ATT would attempt this again with improved products in 1992 without success.


The Bell Picturephone was introduced at the 1964 World's Fair.

Gernsback's prediction for a widespread interactive audio/visual communication would not be realized for a few more decades as there were critical enabling technologies that would first need to evolve.

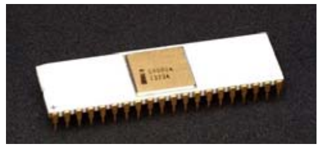
## Computing

Computing machines were developed in the 1950s initially from vacuum tube technology, then later from discrete newly developed transistor circuits. Early computer systems were huge requiring a large, secure, raised-floor, air conditioned room usually with a glass wall for viewing with awe. These large "mainframe" systems were expensive and could only be afforded by the largest businesses, universities, and research institutions. Through the 1960s, mainframe computers gradually became more affordable attracting more corporate customers. In 1968, the newly introduced IBM System/360 sold 1,000 units in the first thirty days. Through the further use of solid state devices and circuit miniaturization, systems were reduced in the 1970s and 1980s to "mini" computers which were still the size of refrigerators with disk and other storage accessories the size of washing machines. These systems were more affordable, enabling more widespread use in business and academia. Brands included IBM, Burroughs, Sperry-Rand Univac, Control Data, Honeywell, National Cash Register, and RCA, and later Hewlett Packard, with IBM the most dominant.

This miniaturization was achieved through the development and evolution of microchips (a.k.a. integrated circuits (IC)). The first true monolithic integrated circuit was developed in 1959 by Robert Noyce at Fairchild Semiconductor. These ICs were initially utilized by the military and aerospace. The manufacturing process continued to improve, and ICs became more and more complex. By 1971, ICs with computational capability were commercially available. These devices enabled innovative consumer products; one of the first were simple four-function calculators which were soon followed by increasingly complex scientific calculators.

Texas Instruments SR-50 Scientific Calculator, 1974. Author's collection.

In 1974, Intel introduced the 8080 which was considered the first commercially usable microprocessor. It contained 6,000 transistors, which is miniscule compared to current transistor densities. The availability of this and other microprocessor ICs ignited the hobby computer market. In 1975, computer kits were introduced — the Altair 8800 and IMSAI 8080 both used the Intel 8080 microprocessor and standardized on an S100 bus; the Southwest Technical Products (SWTPC) 6800 used the SS50 bus and Motorola 6800 microprocessor. The SWTPC was the first system I built; I still have it and, after a little TLC, it works just as it did. Altair was considered the first of this genre, but only by a few months.



Intel 8080 microprocessor, 1974.


IMSAI 8080 computer, 1975. One of the first small-scale computers initially targeted at hobbyists. It was designed using an Intel 8080 microprocessor and S100 bus architecture. Author's collection.

In the 1980s, manufacturers of small-scale computers designed their systems to primarily target either home or small-business customers. Home computers were focused on graphics, games, and home/hobbyist related apps — brands included Apple II, Commodore, Atari, etc.. Computers targeted for business offered Word Perfect, Lotus-123, database, networking, printing, etc., and eventually Microsoft Office — brands included IBM and its many clones, Hewlett Packard, Wang, Xerox, S100 systems, etc..

Gordon Moore, co-founder and Chairman of Intel, made the observation that the number of transistors in an integrated circuit doubles about every two years. Not a law per se, but a projection forecasting future growth which has held since 1975. This growth fueled a rapid and continual increase in computer performance while maintaining affordability. By 1984, IBM and its clones were selling 2 million PCs per year; 6 million per year in 1987; 16 million per year in 1992; and 35 million per year in 1996. In the 1990s, IBM and its clones enjoyed a 90% market share.

From the 1980s, business experienced an enormous shift. With the proliferation of increasingly more powerful but still affordable computing systems coupled with information technology (IT) systems, business was fundamentally changing from relatively slow paper and labor intensive processes to faster more efficient paperless automation. To fully realize this shift, another advance was essential — connectivity of users to host systems, and connectivity of systems to systems.

## Connectivity of Users to Host Systems

Computer usage was increasingly shifting from back-office batch processing to user time-sharing. In the 1960s/1970s, user connectivity to host mainframe systems was via dedicated cabling or a telephone/telegraph leased line. The most efficient arrangement was time-sharing that interleaved a user's typically short bursts of communication with those from other users enabling them all to share precious time on the same host system.

Users could also connect over a telephone line with a modem. In the 1970s, modems were typically acoustically coupled with the telephone and used FSK audio tones in the voice frequency range to be compatible with telephone handsets; consequently this was very slow. ATT prohibited any device to be connected to the network that was also directly connected to user equipment; since acoustic modems were only acoustically coupled, they were allowed. After this restriction was removed (see next paragraph), later modems would connect directly to the user's terminal, and thus could employ higher frequencies and better modulation methods resulting in much faster communications.

Dial telephone with an acoustic modem, circa early 1970s.

By the late 1960s. ATT was a regulated monopoly that tightly controlled the use of its network, valuing voice service above all. Consequently, ATT largely ignored the growing demand for data communications. It only allowed the connection of devices to their network that it manufactured or licensed. In the late 1960s and early 1970s, this resulted in a several lawsuits from modem and voice-terminal manufacturers which resulted in a few small wins but no systemic changes. Responding to increasing pressure, by 1972 FCC made regulatory changes that started to loosen restrictions on the connection of third-party devices to the network including modems. In 1974 the Department of Justice filed an antitrust case regarding ATT's anti-competitive business and financial practices which resulted in ATT agreeing to divest control of its local telephone services leading to its break up in 1982. From then on, users could use the telephone network for data communications, using much improved modems with significantly improved speed and response.

## Connectivity of Systems to Systems

In the 1960s, various inter-network design approaches were explored in interconnecting various university computers and their local networks. Methods employed by telephone communication (circuit switching) and by the telegraph (store-and-forward) were ruled out as too inefficient for computer communications. For example, a circuit switch would dedicate a phone line for the duration of a voice call, if circuit switching were used for computer networks, large amounts of dedicated cabling would be required and each would have very modest bursts of use — this would be hugely wasteful.

An alternative that was proposed independently by Paul Baran and Donald Davies in the early 1960s was packet switching, where the message is broken into many small packets of characters and sent individually. Packets are individually identified so they can be reassembled in the proper order at the receiving end. If a particular packet is lost or defective, then it could be resent without requiring that the entire message be resent. Since computer communications are typically short bursts of data with large gaps, the packets being sent from many different sources could be interleaved using up the gaps, which is much more efficient. Further, packet communications are less error prone and have better error recovery. Consequently, packet switching was adopted for computer networking.

In the mid-1960s, the Department of Defense Advanced Research Projects Agency (ARPA, later DARPA) became interested in promoting a wide-area network connecting universities and science-based government agencies, and soon provided funding and leadership for the development of such a network named ARPANET.

Since the local networks at each computer site could be of arbitrary design and technology, instead of requiring a specific standard design for each connected network, DARPA opted for an Open Architecture and set four criteria: 1) Each distinct network (of arbitrary design) had to stand on its own, and no internal changes could be required of the network before connecting to the APRPANET; 2) Communications would be on a best-effort basis. If a packet didn't make it to the final destination, it would quickly be resent. 3) Black boxes (i.e. gateways and routers) would be used to connect the networks; further, no information would be retained by the gateway about packet flows passing through them thus keeping gateway design simple; 4) There would be no global control at the operations level.

At the heart of this open architecture are two protocols developed in the late 1970s that would work for any arbitrary network. They are, the Transmission Control Protocol (TCP) which is used to establish, maintain, and terminate connections between networks, and the Internet Protocol (IP), which provides a means of addressing and routing communications messages to their destination. Together they are TCP/IP invented by Bob Kahn in 1978. They principally form the layers between the physical networks and the host system where various applications (browser, email, etc.) can run using a variety of other standard protocols.

**Internet Protocol Suite Layers**

| Layer | Purpose | Example Protocol or Standard |
|---|---|---|
| Application Layer | Browser, Email, File Transfer, Streaming, Domain Names, etc. | HTTP, HTTPS, SMTP, POP, IMAP, HLS, FTP, DNS, ... |
| **Transport Layer** | Connection (establish, maintain, terminate), manage packets, error correction | TCP, UDP |
| **Internet Layer** | Addressing, gateway, routing | IPv4, IPv6 |
| Link Layer | Message framing, interface to physical network | Ethernet, 802.11 |

'Internet Layer' above is an early use of the term. Later the term 'Internet' came to refer to the entire wide-area network and architecture described in this section.

ARPANET became functional in 1969 with its first connection between UCLA and Stanford Research Institute (SRI). Because it was funded through DARPA, it was prohibited from being used for commercial purposes. By 1974, it had grown to 46 nodes of university and science related government sites. By 1981 it had 213 nodes. ARPANET was decommissioned in 1990. ARPANET's design, open architecture approach, coupled with technology developments and new protocols including the development of Ethernet (Robert Metcalfe, 1973), the IP router (Ginny Strasizar, 1976), Domain Name Server (DNS) protocol (Paul Mockapetris 1983), firewalls in 1988, guided network evolution and consolidation through the 1980s and 1990s, resulting in the Internet as we know it.

Networks gain momentum as they grow. Metcalfe's law, proposed in 1980 by Robert Metcalfe, who was the inventor of the Ethernet in 1973 and later co-founder of 3Com, states that the influence or financial value of a telecommunications network is proportional to the square of the number of connected users. Connectivity attracts connectivity . . . more is more.  It was true for the telephone system and it's true for the Internet now.  This notion can be metaphorically applied to the exponential adoption and growth of social media platforms and other user-based Internet applications.

## Connectivity of Information

If the 1970s and 1980s were the formation of the Internet wide-area network (the connectivity of users and systems), then the 1990s was the formation of the World Wide Web (WWW or W3), that is, the connectivity of information.

In 1989, Tim Berners-Lee, a British computer scientist working at CERN, proposed a method of linking information at different systems using hypertext, which are the highlighted links you find on web pages.  He also proposed a transport protocol for hypertext called HTTP, which is basically how Internet client-server applications including browsers communicate.  This was refined by the W3 Consortium over the next few years, with HTTP/1.0 made final in 1996. Applications of many varieties sprang up.  In the late 1990s, early Internet portals/search engines included Yahoo!, Excite, Microsoft Network (MSN), Disney's Go, Lycos, and the new upstart Google; early browsers included Netscape/ Mozilla, Microsoft; early Internet applications included Amazon, Auction Web (Ebay), various email apps, Napster, etc.

Growth was dramatic. For example, Yahoo! started in 1994 as 'Dave and Jerry's Guide to The World Wide Web.' In 1995, CHRS member and Board Chairman Philip Monego served as an Interim CEO and Chairman. Within six months he had incorporated Yahoo!, mentored the founders, and secured its first venture capital. In 1996 Yahoo!'s stock sale IPO had the third largest first-day gain on record with a market cap of $896 million; by January 2000, its valuation had grown to $125 billion.  The enthusiasm for Internet growth encouraged speculative and bullish investing in companies both strong and weak creating the Dot.com bubble,.  The bubble peaked on March 10, 2000 and three days later burst; stock values dropped markedly over a two-year period.  Yahoo! survived and continued to expand but many did not.  Many companies with poor fundamentals, or start-ups who burned through venture financing before becoming profitable, went out of business.  Afterward, investments were more cautious and realistic.

Web 2.0, released in 2004, brought functionality that enabled more user-generated content and sharing, leading the way to social media (Facebook, Twitter, etc.), video sharing (YouTube, et al), and other interactive apps that we know today.

In the early 2000s, Internet apps like Skype and iChat were introduced that went well beyond video conference systems, which had limited user access, and made two-way video interaction widely available.  At that point it is fair to say that Gernsback's prediction was realized, but he would probably be curious what might be next, so lets continue a bit more.

## Connectivity Untethered

Access to networks became untethered with the June 1997 release of the 802.11 WiFi standard.  Apple achieved a commercial breakthrough with their 1999 introduction of the Airport WiFi station at an impressively low price point.

Personal communications became untethered with the 1983 introduction of the Motorola DynaTAC 8000x, the first cellphone, invented by Martin Copper in 1973. It used 1G analog cellular network technology and would be available until 1990.  2G digital cellular networks were introduced in 1992 which enabled the beginnings of data services for compatible digital mobile phones. The Apple iPhone, introduced in 2007, was the first Smartphone and used faster, more capable 3G. The iPhone converged telecommunications, computation, and Internet access into your hand or hip pocket, providing connectivity from almost anywhere.

DynaTAC held by inventor Martin Cooper in 2007.

## So Here We Are

The Internet has become a dominant avenue of connectivity with friends, family, the workplace, interest groups, ..., etc.; however, personal connections are increasingly virtual.  It provides information at your fingertips or vocal query, which is quite useful for doing homework or writing this journal article.  It enables us to work from home.  We can purchase most anything from our living room, or wherever we happen to be.  It's become a podium of opinion by anyone, anywhere, anytime.  It has made us weary and more suspicious, and it has diminished our sense of privacy, confidentiality, and anonymity.  The Internet truly has become disruptive, reshaping our culture and world view.

Gernsback lived in a much simpler time when Spam only came in a can.

The prophecies of Gernsback in May 1926 took a bit longer to come to fruition than he imagined. Television wasn't just around the corner, but would take three decades to mature and receive widespread use. It would be more than seven decades before it could be commonplace to visually propose marriage at a distance. He gave no indication that he foresaw the accompanying world-wide-web information network and there is no way he could have fully appreciated its impact.

Technologies Gernsback knew have shifted considerably from his day nearly a century ago. Radio has become the backbone of wireless WiFi and cellular networks, but the radio we knew growing up has become just a curious relic. AM is dead. Televisions have become Smart, but are little more than browsers for streaming content via the internet, cable or satellite. And technologies continue to march forward, evolving, and bringing more disruption and cultural change.

Conventional wisdom can be a familiar and comfortable box in which disruptive technologies can be seen as a most annoying distraction and easily discounted. Here are a few examples of conventional wisdom reactions that could have adversely influenced the technology chains that ultimately led to the realization of Gernsback's prophecies:

> "This 'telephone' has too many shortcomings to be seriously considered as a means of communication. The device is inherently of no value to us." — Western Union memo, after Alex Graham Bell offered to sell them the rights to the telephone, 1876.

> "The wireless music box has no imaginable commercial value. Who would pay for a message sent to nobody in particular?" — An associate's response to David Sarnoff's proposal for investment in the radio in the 1920s.

> "While television may be feasible theoretically and technically — commercially and financially I consider it an impossibility, a development of which we need waste little time dreaming." — Lee DeForest, American radio pioneer, 1926.

> "Television won't be able to hold on to any market it captures after the first six months. People will soon get tired of staring at a plywood box every night." — Darryl Zanuck, 20th Century Fox. 1946.

> "But what . . . is it good for?" — Engineer at IBM's Advanced Computing Systems Division commenting on the microchip, 1968.

> "There is no reason anyone would want a computer in their home." — Ken Olsen, president, chairman and founder of Digital Equipment Corp., 1977.

> "So we went to Atari and said, 'Hey, we've got this amazing thing, even built with some of your parts, and what do you think about funding us? Or we'll give it to you. We just want to do it. Pay our salary, we'll come work for you.' And they said, 'No.' So then we went to Hewlett-Packard, and they said, 'Hey we don't need you. You haven't got through college yet.'" — Apple Computer Inc. founder Steve Jobs on attempts to get Atari and H-P interested in his and Steve Wozniak's personal computer.

> "The idea of a personal communicator in every pocket is a "pipe dream driven by greed." — Andy Grove, CEO of Intel, 1992.

> "There's no chance that the iPhone is going to get any significant market share." — Steve Ballmer, CEO of Microsoft, 2007.

Looking forward, seeing that Internet has become a playground for Artificial Intelligence (AI), a technology we are just beginning to experience. Gernsback might ask, "What will be the impact of AI in the future?" For now, AI behaves according to what it's learned and taught. Will it eventually author a great novel, a Pulitzer winning drama, or profound scientific theory? Perhaps with help from AI image generation, might it become the next YouTube rock star? Will AI persuade us to embrace the latest fashion trends, or perhaps use its mined personal familiarity about us to tell us what we must do to be "acceptable", or how to be cool? Could AI become a licensed psychiatrist? Will AI promote philosophical perspectives, seemingly plausible conspiracy theories, or contrived convenient "truths"? How will we know if what we see, read, or hear is AI or not? How will we know fact from fiction? When will Artificial Intelligence no longer be considered artificial? Ultimately, which way will the scales tilt — will AI serve to help and benefit us, or will AI serve to deceive and exploit us, even facilitate dominance? How will culture be reshaped?

Looking forward, I wonder what Gernsback would say now? Perhaps he might agree with Yogi Berra who observed:

**"The future ain't what it used to be."**

---

## Sources

Gernsback, Hugo *Radio News, May, 1926*; Hugo Gernsback, publisher.
Journal of the California Historical Radio Society, Special Edition - Television; Vol. 38, No. 3; 2019.
Leiner, B., et al; *Brief History of the Internet;* Internet Society, 1997.
Pelkey, J., Russell, A., Robbins, L,; Circuits, Packets, Protocols: Entrepreneurs and Computer Communications - 1968-1988; ACM; 2022.
Pelkey, James; *The History of Computer Communications*; 2013; https://historyofcomputercommunications.info/ .
Wikipedia - various topics.

◊

## Where There's Radio, There's Bud

By John Okolowicz

Remember some of those old advertising jingles that actually made the jump to popular success? I'm talking about hummable ditties like Alka-Seltzer's "No Matter What Shape (Your Stomach's In)" (1966), Benson & Hedges' "The Disadvantages of You" (1967), Pepsi's "Music to Watch Girls By" (1967), and Coca Cola's biggie "I'd Like to Teach the World to Sing" (1971).

Budweiser's theme achieved a similar smidgen of popular success but with a twist. All told, it was released as a 45 record plus two LP albums—and all of them on different record labels. And--the record albums' cover art were clones of Budweiser's magazine ads.

Anheuser-Busch had a long close relationship with the D'Arcy Advertising Agency going way back to the 1920s when Prohibition was still the law of the land. Robert E. Johnson, head of their radio/television department, originated their heart-warming slogan "Where there's life, there's Bud" to promote Budweiser, their premier product. For the next decade that became the focal point around which their entire printed marketing campaign was directed. Bud's ads appeared relentlessly in *Life, Saturday Evening Post, Time* and a few other prominent magazines of the era.[1]

Eager to expand into the fast-growing radio/TV market, a catchy tune was created by Russ David (1914-2003), a prominent St. Louis bandleader and pianist from Anheuser's corporate home town of St. Louis. He wrote the melody in collaboration with Lawrence Welk's bandleader, George Cates (1911-2002).

It was a great combination. George was basking in his new-found status as a pop star for his instrumental medley of the "Theme From Picnic/Moonglow." It climbed all the way up to number seven on the Billboard Hot 100 chart in April 1956. It was produced by Decca Records' subsidiary Coral label. Cates followed that with his arrangement of "Where There's Life" and by September it slowly crept up to number 75 on Billboard's list.

Anheuser-Busch and D'Arcy then decided to form a marketing alliance with a new company, Columbia Records, dismissing the minor success of Decca's record. *Cash Box*, a musical trade journal, made the announcement in March 15, 1958 under the headline: "Columbia and Budweiser Beer Set Tie-In for New Kaye LP." It went on to explain:

> "Columbia Records and Budweiser Beer Company are launching a gigantic, all-media push on Sammy Kaye's newest album, 'Midnight Serenade,' which features the brewery's theme, 'Where There's Life' as one selection. 'This album will be a featured part of extensive national advertising and promotion,' reports Columbia Advertising and Sales Promotion Director Arthur Schwartz, 'deriving the benefits of half a million dollars in the overall total budgets of the two companies during the run of the program.'"

Figure 1 shows Columbia's album cover alongside Budweiser's near-identical magazine ad. The album featured a collection of hum-drum songs of the era ("Did You Ever See a Dream Walking," "Dream a Little Dream of Me," "I'll See You in My Dreams" etc.) with Budweiser's advertising theme song stuck at the end (Side 2 Track 6) as if it was an afterthought. Adding to the mystery and unlike most record albums, there were no explanatory liner notes on the reverse side of the album jacket, only references to the other LPs in Columbia's vast catalog. So, as a marketing tool, this album was poor at best.


Fig. 1: *Midnight Serenade*, Columbia LP, CL-1107 (on left); Budweiser ad from *Life* magazine March 31, 1958 (on right).

Nevertheless, Columbia made a few other unmarked LPs (or possibly they were EPs) for Budweiser's use as a promotional item as shown in Figures 2 and 3. The back side of one of them (Figure 4) actually shows liner notes under the title: "58 Sounds of Budweiser," but there is no indication of what songs were on it.


Fig. 2: Columbia/Budweiser promo (on left); Budweiser ad from *Life* magazine January 28, 1957 (on right).


Fig. 3: Columbia/Budweiser promo LP/EP (on left); Budweiser ad from *Life* magazine February 23, 1959 (on right).


Fig. 4: Columbia promo album reverse side.

By 1960 it may have occurred to the execs at Anheuser-Busch that the business arrangement with Columbia was not as successful as expected and so they gave it another try using RCA, Columbia's biggest competitor.

RCA, under the tight leadership of David Sarnoff, maintained a healthy rivalry with CBS. The battle was always a bit uneven because RCA had a powerful manufacturing capability, while CBS had very little, but they did manage to have a manufacturing research facility led by Dr. Peter Goldmark.

The competition between RCA and CBS had deep roots. The development of and success of the LP over the 45 RPM for recording concerts and operas was a significant coup for CBS and their chief engineer, Dr. Goldmark.

On the other hand, in the battle to establish a color broadcasting standard, RCA's color CRT eventually outperformed CBS's mechanical spinning wheel making RCA the clear winner and dominant in color broadcasting.

RCA's collaborative announcement appeared in *Billboard* magazine on February 1, 1960, under the title: "Victor, Bud in Album Hook-up":

> "RCA Victor has set up joint promotion with Anheuser-Busch, manufacturers of Budweiser Beer, centering around the new Russ David pop album titled, 'Where There's Life.'. . . . . the Album title is taken from Budweiser's ad slogan, 'Where There's Life, There's Bud.' All songs in the package use the 'Life' theme in titles, such as 'Ah, Sweet Mystery of Life,' 'Life Is Just a Bowl of Cherries,' etc.
>
> Budweiser will use the album cover art in ads, and will run full page ads featuring "Where There's Life" in *Saturday Evening Post, Life, Look, Time* and other national magazines. . .
>
> RCA Victor will advertise "Where There's Life" album in half column ads in *The New Yorker, Sports lllustrated, Playboy* and other national mags. "

Figure 5 shows the RCA LPM-2191 (mono version shown but it was also available in stereo) next to its Budweiser magazine advertisement. This LP had the good sense to include liner notes (Figure 6) that complemented the content. Here are some highlights:

> "Conceived and produced by Bob Johnson . . .
>
> The music in this album serves as a sort of swinging exponent of the subject. Not only does each of the twelve songs deal with a particular facet of life, but the sound and tempos are well calculated to enliven most any kind of party. . .
>
> The man responsible for the lively sounds heard within is Russ David. The Missouri born musician cut his arranging teeth with such pioneer swing bands as Isham Jones and Ben Pollack. He has appeared as piano soloist with the St. Louis Symphony and is currently the musical director of that city's NBC outlet. On this recording he not only

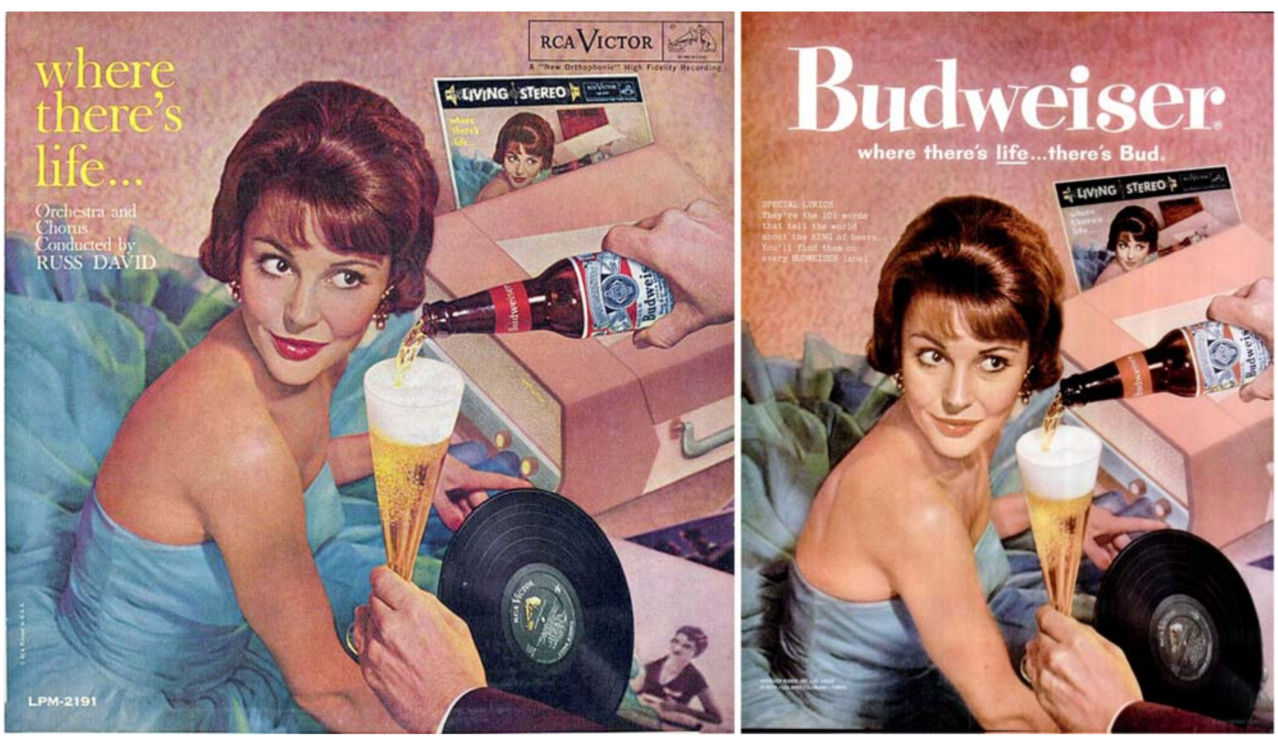



Fig. 5: RCA LPM-2191 (on left) and Budweiser ad from *Life* magazine February 15, 1960 (on right).

> conducts the orchestra and vocalists but also claims the credit for arranging all of the numbers. And if that weren't enough, the quadruple-talented Russ also assists at the piano and serves as vocalist for Life is *Just a Bowl of Cherries.*
>
> Two of the songs on the record were composed especially for the occasion. The first is the title number, *Where There's Life*, which sets the lively mood that prevails throughout. The second is the bright and tasteful *Love the Life I'm Living.*"

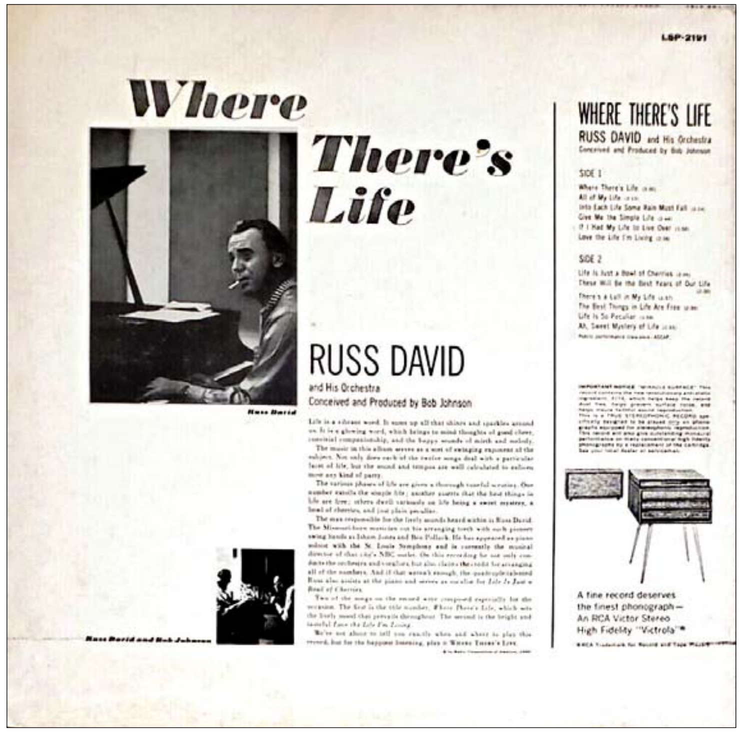


Fig. 6: Reverse side of RCA album showing liner notes.

Realizing that there was no benefit in keeping the existing "Midnight Serenade" cover art, Columbia quickly reissued it to depict a nighttime scene and eliminate the prior visual reference to beer consumption (Figure 7).

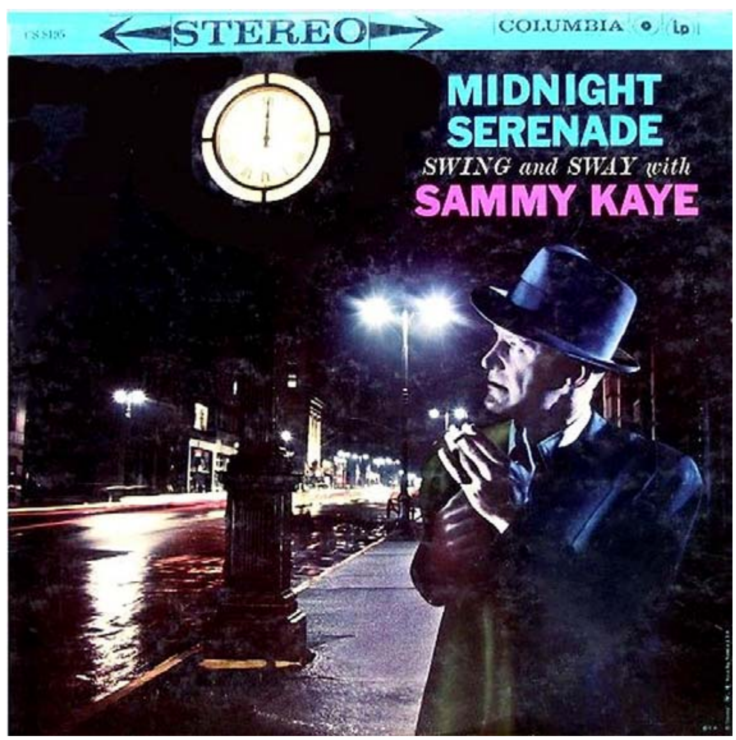


Fig. 7: "Midnight Serenade" reissued cover art (stereo version CS-8195).

The *Encyclopedia of Advertising* claims that some artists seem to have a natural ability to create jingles that become hits, citing Roger Nichols as a prime example. When Richard Carpenter first heard Crocker Bank's short advertising jingle, which he wrote (in conjunction with Paul Williams), he immediately recognized its pop music potential. He quickly contacted Paul Williams to ask if he would be willing to expand it to a full song, and the result: "We've Only Just Begun" became a smash hit for the Carpenters and A&M records in 1970, reaching #2 on Billboard's list. Nichols repeated that success when he created "The Times of Your Life" (in collaboration with Bill Lane) for Kodak. Paul Anka picked up the ball on this one and ran it up to #7 in 1975.

Bobby Darin, as we all know well, was a super star singer and song writer, nevertheless, his venture into advertising did not yield the same success as it did for Roger Nichols. "She's Tanfastic" says it all. It may take the Guiness prize for the most obscure ad jingle ever made. Tanfastic was the name of a 1960's suntan lotion made by White Stag. Newspaper and magazine advertisements (Figure 8) urged readers to get this "exclusive collector's item with that swingin' Darin beat! Bobby wrote and sings both songs—as


Fig 8: Tanfastic Sunday newspaper ad from June 1960.

only Bobby can. . . .Simply send 50¢ for each record." "She's Tanfastic" is backed with "Moment of Love" on the flip side (Figure 9). Neither song charted on Billboard and are not even listed in Darin's Wikipedia discography. For those with inquiring minds, here are the opening lines:

> "I got a girl, she's so tanfastic
> If she don't love me I'll do somethin' frastic
> I call her up and she ain't home
> Then I remember she's got no phone
> I'm so in love, I don't know what I'm singin'"

A far cry from Bobby's memorable 45s of "Splish Splash" and "Beyond the Sea," but we can only hope that he was handsomely rewarded by Stag's CEOs.

Over the years there have been many examples of popular songs that were hijacked for use in TV commercials (not to mention for use in political rallies), but the transformation from commercial jingle to popular song remains a rather rare one.


Fig 9: *She's Tanfastic* is the flip side of the *Moment of Love* 45 RPM record by Bobby Darin.

## Reference:


1. "Where there's Radio, There's Bud," *U.S. Radio* magazine February 1960 p18-21.


◊

# The Colossus of Ultra

By Richard Watts

Continuing with my prior article in the Spring/ Summer 2023 journal issue, *The Enigma of Ultra,* of my visit in Fall 2022 to Bletchley Park and the British National Museum of Computing, a critical Ultra effort in WWII was the decryption of teleprinter messages.

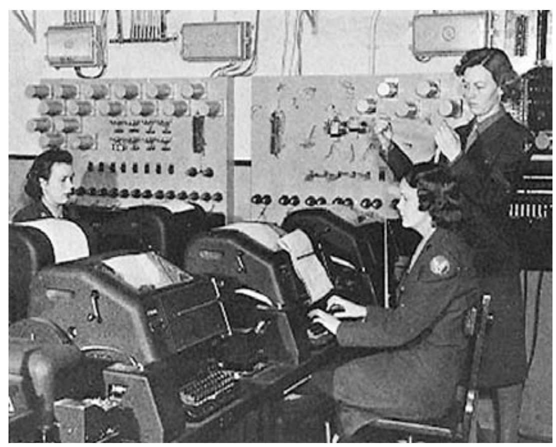
Bletchley Park mansion. The mansion house with the odd architecture and carriage houses behind served as work space for the first staff. As staff increased, several barracks-like wooden buildings called Huts and, later, block buildings were built on the grounds. Source: Bletchley Park website

During WWII, Ultra was a trilogy of listening, deciphering, and understanding enemy (primarily German) military signals communications. Ultra was more secret then 'Top Secret', it was 'Ultra Secret.'

The German High Command utilized teleprinters for most of their communications between headquarter divisions. Their messages were often long, 1000 characters or more, and not suited for morse code or the slow Enigma encryption process discussed in the previous article. The Germans also utilized a more complex mechanical device than Enigma that proved a greater challenge for the British code breakers to solve. Once the method of decryption was understood, the decryption process evolved and became more efficient in several inventive ways which included the design and construction of the first digital computer pre-dating ENIAC, named Colossus.

## Teleprinters

The teleprinter, also known as a teletypewriter or teletype for short and abbreviated as TTY, is an electromechanical machine used to print messages, much like a typewriter. It prints messages on a roll of paper in response to a signal received from another machine. The connection between machines can be hardwired or via a radio link.



Teleprinters used in England during WWII. Source Wikipedia.

The teleprinter has evolved from a printing device for morse telegraph in the mid 1800s to its more current form by the early 1900s.

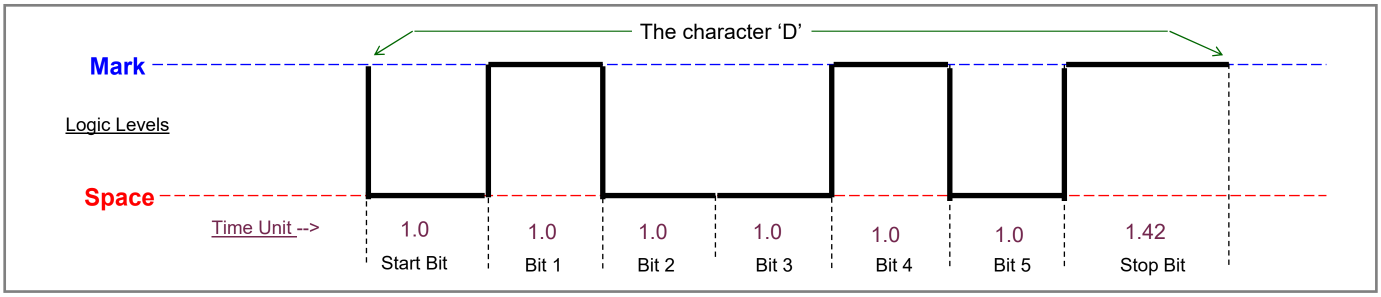
The teleprinter signal format is called Baudot code. Emile Baudot patented the first version in 1888. In 1901, Don Murray modified the code adding the Carriage Return and Line Feed characters.

The character is made up of five elements, each element can either be "Mark" or "Space" which are the two logic levels in teleprinter circuits; the mark level is when current is flowing, the space level is when the circuit is open (no current flow). For example, in the table below, the 'A' character is formed as a mark, mark, space, space, space; similarly a 'B' is a mark, space, space, mark, mark. Note, the space logic level shouldn't be confused with the 'Space' character.

| LETTERS | | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T | U | V | W | X | Y | Z | CARRIAGE RETUN | LINE FEED | LETTERS | FIGURES | SPACE | ALL-SPACE NOT IN USE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| FIGURES | | – | ? | : | WHO ARE YOU | 3 | % | @ | £ | 8 | BELL | ( | ) | . | , | 9 | 0 | 1 | 4 | ' | 5 | 7 | = | 2 | / | 6 | + | | | | | | |
| CODE ELEMENTS | 1 | • | • | | • | • | • | | | | • | • | | | | | | • | | • | | • | | • | • | • | • | | | • | • | | |
| | 2 | • | | • | | | | • | | • | • | • | • | | | | • | • | • | | | • | • | • | | | | | • | • | • | | |
| | 3 | | | • | | | • | | • | • | | • | | • | • | | • | • | | • | | • | • | | • | • | | | | • | | • | |
| | 4 | | • | • | • | | • | • | | | • | • | | • | • | • | | | • | | | | • | | • | | | • | | • | • | | |
| | 5 | | • | | | | | • | • | | | | • | • | | • | • | • | | | • | | • | • | • | • | • | | | • | • | | |

Baudot/Murray code character table. A mark is indicated by a black dot • . Source: Wikipedia.

The five code elements or bits are sent serially. The idle condition is a continuous mark level on the line. To frame each character to enable the receiving machine to discern individual characters, each character is preceded by a 'start bit' and followed by a 'stop bit.' A 'start bit' is a space that is the normal bit length in time. The next five bits represent the character and are of normal length. The 'stop bit' is a mark that is 1.42 times longer than the normal bit length. The longer stop bit duration allows the receiving machine to synchronize for the next character. Computer implementations of Baudot code applications typically use a stop bit length of 1.5 or 2.0 as the 1.42 bit length is difficult to implement in computer code.

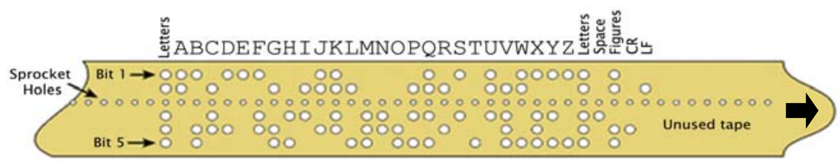



Teleprinter signal levels in the transmission of a character.. Left to right: the start bit is a space. The next five bits represent the character, in this case a mark, space, space, mark, space is a 'D'. Last is a stop bit that is a mark 1.42 times the bit length. If another character is sent, then it follows immediately with another start bit, and so on. If the message has ended, then the line will idle at the mark logic level.

The common baud rate or the speed the characters were sent was between 45.5 (60 words per minute) and 50 (66 words per minute. The bit length at 45.5 baud is 22ms and the bit length for 50 baud is 20ms. Other baud rates were possible.

Since there are only five bits per character, then only 32 characters are possible ($2^5$=32). Actually there can be only 31 as a character with five space logic levels is not defined. Consequently, a teleprinter keyboard only has 31 keys.

Teleprinter keyboard. It has 32 keys. Each key can produce two characters, the alternate upper character is accessed by first pressing the Figs (figures) key. Access to the lower characters can be restored by pressing the Ltrs (letters) key. Source: Wikipedia.




Teleprinter paper tape hole patterns for each of the characters. A hole represents a mark and no hole represents a space. The tape is driven with a sprocket that aligns with the tiny holes punched by the manufacturer down the center of the tape. Source: CryptoMuseum.com

Teleprinters can have a paper tape reader/ punch as part of the machine or as an accessory. A message can be read from tape and sent as if it had been typed. Conversely, a received message can be punched to tape as it is printed. The density of a punched tape is about 10 characters per inch; long messages could produce a very long tape.

The keyboard of the German teleprinter had a slightly different arrangement to accommodate a difference in the most used keys of the German language. See the Lorenz T32 teleprinter on the next page.

The Germans encrypted the message produced by the teleprinter using a device manufactured by Lorenz. More details about this device to follow. Once encrypted, the message was then transmitted.

Germans modulated the Baudot signal in two audio tones, a technique call Audio Frequency Shift Keying. The mark bit is modulated as one frequency while the space is modulated as another. This technique is used in amateur (Ham) radio teletype (RTTY); Those two tones used are 2125 Hz for a mark and 2295 Hz for a space. The difference, or shift, is 170Hz. Germans used three pair of frequencies shown in the table right.

| German AFSK Frequencies | | | |
|---|---|---|---|
| **Logic Level** | **Channel 1** | **Channel 2** | **Channel 3** |
| **Mark** | 540Hz | 1260Hz | 1980Hz |
| **Space** | 900Hz | 1620Hz | 2340Hz |

Typical AFSK frequencies used by the Germans. Source: Breaking Teleprinter Ciphers at Bletchley Park, Appendix A.

The Germans used all three sets of frequencies simultaneously. They modulated the same message with each pair of tones, then mixing them into a single phone signal which was then modulating with the HF carrier and transmitted. Using the three tones simultaneously provided signal diversity that would provide more successful reception when selective signal fading occurred.

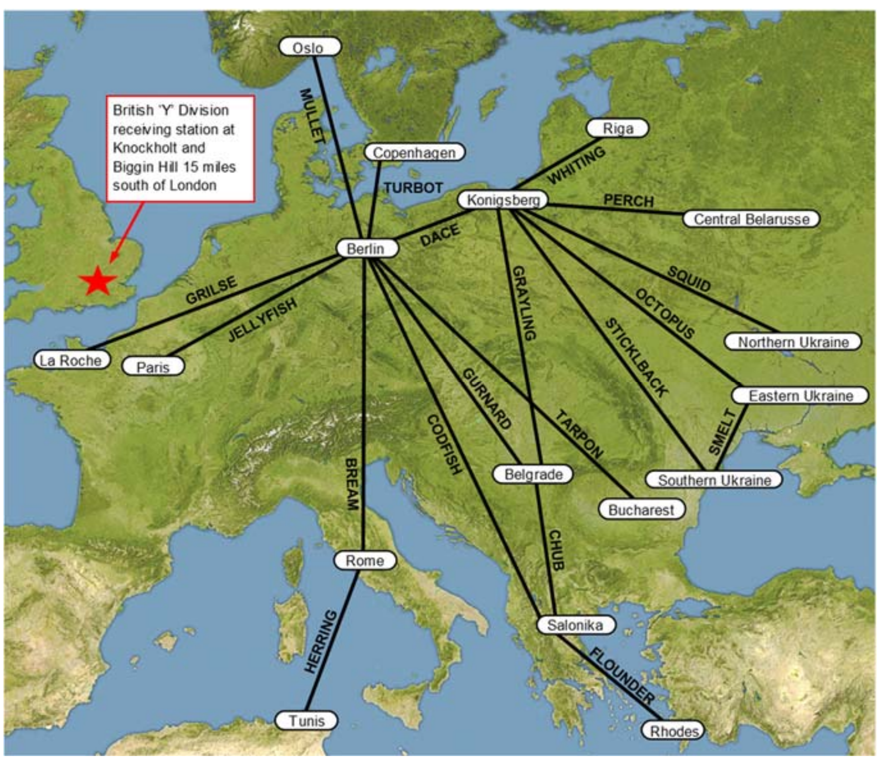
On the receiving end, a set of filters was used to segregate the frequencies to detect mark/space patterns. These mark/space patterns produced by the three frequency pairs were compared to for agreement and error correction was applied as needed. The exact method the Germans used is not known.

In the latter part of 1944, the Germans began to use RF frequency shift keying (FSK) where they would shift the carrier 360Hz to differentiate between mark and space.

From 1942, encrypted teleprinter messages were the primary form of communication of the German High Command. The map below shows the configuration of the teleprinter network linked by radio links. The number of links grew from its introduction in 1942 to six links by July 1943 and to 40 by the end of the war. The British referred to the entire network as Tunny (i.e. tuna). The British also used fish names for the links.

1936 German Lorenz T32 teleprinter (cover removed). It includes a tape reader/punch. Its keyboard has differences from a QWERTY layout for the German language. For example, the QWERTY 'Y' has been replaced with a 'Z'. Source British National Museum of Computing.

The map also shows the location of the British 'Y' Division interception site in England in the area of Knockholt and Biggin Hill in Kent (about 15 miles south of London). As discussed in my prior article *The Enigma of Ultra*, 'Y' Division was responsible for all radio interception, and forwarding to Bletchley Park for processing. More details about the interception to follow.




Map of the German high command radio network of Lorenz secure teleprinter traffic sometime between mid 1943 and mid 1944. The British gave each link a nickname of a fish. The nickname for the entire network was Tunny (i.e. Tuna). Sources: Europe map from Wikicommons. Network adapted from Jack Copeland colossus-computer.com.

## The Encryption of German Teleprinter Messages

Germans primarily used the Lorenz SZ40 (1940) and later model SZ42 (1942) in-line cipher attachment to Lorenz teleprinter like the T32 above to encrypt teleprinter messages.

It would be used both for encryption of messages produced by its attached teleprinter/tape, and decryption of received messages received from another station for printing and/or punching tape.

Designed in the 1930s, it was based on an encryption method for securing teleprinter messages patented by Gilbert S. Vernam in 1919 for AT&T.

The Vernam Cipher is based on **Exclusive OR logic** (abbreviated XOR). An Exclusive OR has the behavior that in the cases when its two inputs are the **same**, then its output is a logic **'False'** or in the case of teleprinter signal levels, the output is a **'Space'**. Conversely, in the cases when its two inputs are **different**, then its output is a logic **'True' or a 'Mark'**. The truth table at right shows all four cases of XOR'ing two inputs.

**Exclusive OR (XOR)**

| | Input A | Input B | Output |
|---|---|---|---|
| Case 1 | Mark | Mark | Space |
| Case 2 | Space | Mark | Mark |
| Case 3 | Mark | Space | Mark |
| Case 4 | Space | Space | Space |

In each case, XOR'ing Input A with Input B will produce the corresponding Output. If the inputs are the same, the output is a Space; if different, the output is a Mark.

Another symbol for XOR is ⊕. For example,

Input A 'Mark' ⊕ Input B 'Mark' = Output 'Space'.

One feature of XOR logic is that, in a sense, it is reversible. If an Input is XOR'ed with the Output, then the other Input value will result. For example,

Input A 'Mark' ⊕ Output 'Space' = Input B 'Mark'.

**To put it more generally, for each case in the table, XOR'ing the values in any two columns of a row will produce the value in the third column of that row.**

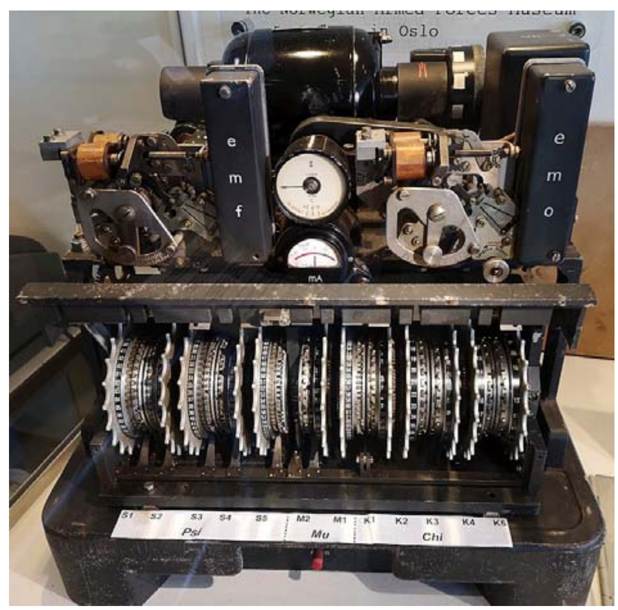
This is a useful feature that enables it to be used for encryption. To encrypt a message, the plaintext message is XOR'ed with a key to produce an encrypted message. To decrypt, the encrypted messages is XOR'ed with the same key to produce the plaintext message. It's reversible. **Curiously, it follows that XOR'ing the plaintext message with the encrypted message would reveal the key, which is very useful for cryptography.**

Gilbert Vernam envisioned using a very long key tape to provide a theoretically unbreakable cipher system. However, the tape would be of such great length that in practice it would be unworkable. To have a more practical key, L. F. Morehouse patented the idea of using two short tapes that are of different lengths that are relatively prime to each other instead of one long one. The two tapes would be run simultaneously and XOR'ed together to produce a key stream that would then be XOR'ed with the message. For example, if one tape were 999 characters and the other is 1,000 characters, then running them on two tape readers simultaneously while XOR'ing them together would produce a keystream of 999 x 1,000 = 999,000 characters before repeating. This proved to be workable.

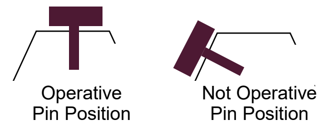
When the Germans designed the Lorenz SZ40 cipher attachment, they were fully aware of the Vernam and Morehouse patents. However, the designers did not want to rely on a system where the encryption key was distributed on tape as the process would be error prone and vulnerable. Instead they designed a mechanism with a set of rotating wheels to produce the key based on a initial wheel settings.

The Lorenz SZ42 has twelve wheels that can be seen on the front that are divided into three groups. Bill Tutte of Bletchley Park who is credited as the principle person to break the Lorenz cipher named the groups accordingly. The rightmost five are Chi ( χ ) wheels; two wheels in the center are motor or mu (μ) wheels; and the leftmost five wheels are Psi (ψ) wheels. Later after the war, Bill Tutte moved to Canada and was awarded one of Canada's highest honors, the Officer of the Order of Canada. In the citation his accomplishments were described as one of the greatest intellectual feats of WWII.

The wheels rotate independently on a common axis. Each wheel has a prime number of pins around its circumference. Each time a character is processed, each wheel rotates by one to its next pin position; since each wheel has a unique number of pins, the periods of rotation are unique for each wheel. Chi wheels always rotate with each character sent. However, the Psi wheels don't always rotate each time because they are triggered to rotate by the motor wheels, as shown in the diagram on the next page.




Lorenz SZ42 cipher machine with cover removed on display at the British National Museum of Computing. This is the later model of the SZ40 introduced in 1940. There were minor differences in the appearance of the models. Photo by Ted Coles


Each pin can be toggled into an 'operative' or 'not operative' position.

In the 'operative' position, the bit to be acted on will be reversed (Mark to a Space or vice versa).

If the pin is in the 'not operative' position, then the bit is unchanged.

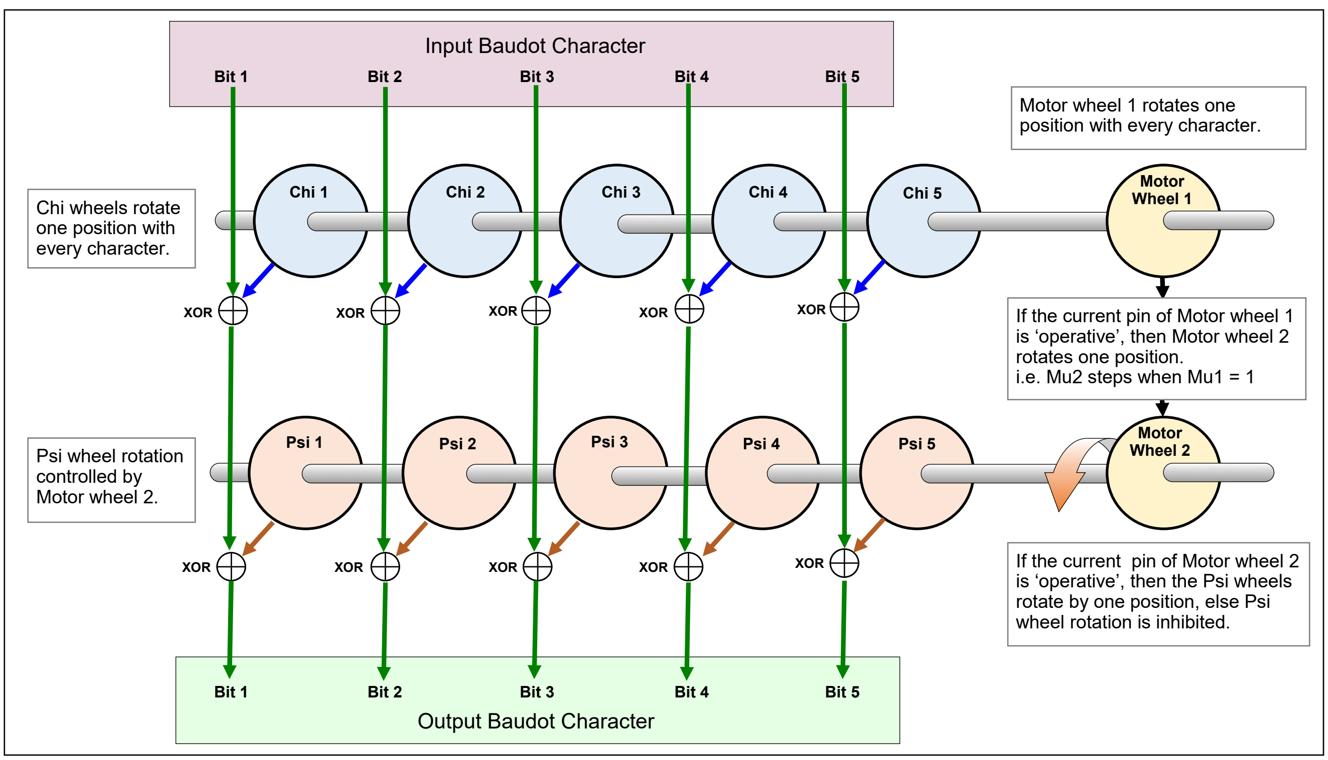
**Lorenz SZ40, SZ42 Wheel Groups**

| | Psi Wheels | | | | | Motor Wheels | | Chi Wheels | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Wheel** | Psi 1 | Psi 2 | Psi 3 | Psi 4 | Psi 5 | Motor 2 | Motor 1 | Chi 1 | Chi 2 | Chi 3 | Chi 4 | Chi 5 |
| **# Pins** | 43 | 47 | 51 | 53 | 59 | 37 | 61 | 41 | 31 | 29 | 26 | 23 |

The Lorenz wheel groups and their attributes.

The key was set in two ways. First, each pin of each wheel could be toggled 'operative' or 'not operative'. Secondly, the wheels could be rotated to a prescribed index position using the thumbwheel rings. In October 1942, the procedure was to change the Chi and Psi pin patterns at the beginning of the month; motor wheel pin patterns were changed daily. Starting in July 1944 the Chi and Psi wheel pin patterns were also changed daily. A unique wheel setting for each message was chosen at random by the originating operator and communicated to the receiving operator in the clear.

To encrypt a message, the machine XOR's the bits of the character with the Chi wheels, then XOR's those bits with the Psi wheels. The Chi wheels advance after each character, however, the advancement of the Psi wheels is more irregular and controlled by the motor wheels as described below. The purpose of this is to make the encryption appear random and remove statistical regularities. Also XOR'ing the message with two sets of wheels Chi and Psi has the effect of extending the length of the key, analogous to the method Morehouse patented using two key tapes. The Lorenz cipher key space, that is total number of key combinations, is on the order of $10^{150}$. which is huge. The result is an encryption system that was extremely difficult to break. The Germans must have thought it impregnable. However . . .




Operation of Lorenz SZ42 wheels. The bits of the Baudot input character are XOR'ed with the respective Chi wheels according to the current pin of each Chi wheel. Those bits are next XOR'ed with the respective Psi wheels according to the current pin of each Psi wheel. Chi wheels then advance forward one position. Psi wheels may advance forward one position as well if the current pin of the Motor 2 wheel is 'operative', else the Psi wheels don't advance this cycle. The Motor 1 wheel advances after each character like the Chi wheels. The Motor 2 wheel advances if the current pin of Motor wheel 1 is 'operative'.

## Breaking the Lorenz Cipher

In the Summer of 1940, a team in England listening for German radio transmissions heard strange signals that were later identified as Hellshreiber transmissions, an early form of fax that was in use in Germany until it was replaced with teleprinters in 1941. Early in 1941, non-Hellshreiber signals were detected coming from German occupied Europe. By mid 1941, they were identified as teleprinter messages. Some of the early messages were sent in plaintext prior to the use of the Lorenz cipher system by the Germans.

This began an investigation that demonstrated genius and creativity at several levels. Over several months in 1941, the cryptographers at Bletchley Park were able to determine the structure and design of the Lorenz cipher system without ever seeing one or having any information about it.

The cryptographers were fully aware of the Vernam and Morehouse ciphers and were also aware that the Germans used pinwheel cipher approaches. The first break was made when on August 30, 1941 two versions of the same 4000 character message was received that had been sent twice with the same key. The first message had been signaled as garbled by the receiving operator, so the sending operator had to resend it. For some reason the message was processed by hand instead of using an automated method such as punched tape. In typing the second message, the operator out of frustration or laziness abbreviated a few words and made a few punctuation changes that created small differences between the two messages. Then sending operator made one of the cardinal sins of cryptography by using the same key for both messages. That mistake enabled a breakthrough.

At Bletchley Park, Col. John Tiltman, a gifted cryptanalyst, analyzed these messages superimposing them to look for differences, a technique called "in depth" and using "cribs" which are common terms, sentences, and abbreviations. After ten days of tedious work, he had recovered both the plain text messages and the key. The British now knew the approach the Germans were using for encryption.

Col. John Tiltman, first to break a Tunny message. Bletchley Park.

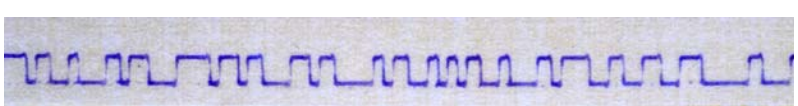
Next was to determine the design of the machine and the keying process. The research division determined that there must be twelve wheels of different rotational periods composed of two sets of five wheels (a deduction given that Baudot characters have five elements or bits), plus two more wheels. Bill Tutte, a young chemistry graduate, joined the Bletchley Park cryptanalyst team. He followed some insights from the team that there might be repeating cycles. So he focused on analyzing the channels of bits (all the bit 1's, bit 2's, etc.). He observed there were repeating patterns of two cycles in each bit. He found that channel 1 had two interacting repeating cycles of 41 and 43. They were named Chi and Psi. They behaved in an analogous way as the Morehouse two-tape system. With Bill Tutte's breakthrough, the entire research section was devoted to this effort and went on to determine the repeating periods of the other four channels.

It was also apparent that the Psi repeating cycles were irregular. This was attributed to the remaining two wheels that they named motor wheels. They determined how that worked and the repeating periods of the motor wheels.

Within a year of intercepting the first messages in mid 1941, they understood the design of the Lorenz cipher system.

By then German teleprinter radio relays were intercepted regularly by 'Y' Division at Knockholt and Biggin Hill. After demodulating the signal with filters, it was printed on an undulator producing a strip representing the signal of marks and spaces. They couldn't use a teleprinter because German teleprinters were faster than British devices.

An undulator on display with a radio of the era at the British National Museum of Computing.



Strip printed by an undulator similar to the one at Bletchley Park. Source: Wikipedia

The printed message was then interpreted separately by two operators who each keyed what they saw onto paper tape. The resulting two tapes were then compared and, if fewer than six errors were found, was then forwarded to Bletchley Park. These messages could be quite long even though Germans limited message length to 10,000. Lorenz operators often combined shorter messages into one long transmission. Messages were typically as many as 25,000; one was even 67,000 characters long.

The nickname "Tunny" (a.k.a Tuna) was the nickname the British gave Lorenz ciphered traffic. However note: in the literature, Tunny can be ambiguous. Authors use Tunny to refer: 1) to an experimental German teleprinter link between Berlin and Athens used in 1942; 2) the entire Lorenz network and its traffic; 3) the Lorenz SZ40 and SZ42 cipher machine (sometimes also called "Fish"); 4) the machine built by the British to emulate the Lorenz cipher machine. I will use "Tunny" alone for the Lorenz ciphered traffic, and "British Tunny" to refer to the device built by the British.

## Deciphering Messages Using Manual Methods

The Lorenz cipher key was defined by toggling the pins to their 'operative' or 'not operative' positions on each of the Chi, Psi, and Motor wheels. Until July 1944, the Chi and Psi pins were set monthly; the motor wheel pins were set daily. From July 1944 pin settings on all the wheels were changed daily. There were a total of 501 pins to adjust. The German strategy for the pin patterns was chosen so as to have no statistical significance; that is, the chances that any pin was 'operative' was 50-50. This applied to the pin settings for an entire wheel.

An observation regarding statistical significance: one extreme example is that if all the pins of every wheel were set to their 'not operative' position, then no encryption would be done — the plain text input would not be changed in the output. The other extreme case is that all the pins are set to 'operative' which would be almost as trivial to solve. Those two cases are instances of maximum statistical significance. Conversely, to the Germans' point, the optimal and most difficult to break is when the pins are set to minimize statistical significance, that is to minimize any discernable pattern in the encrypted message.

The Lorenz cipher machine key was also defined by the start positions of each wheel. For each message sent, the operator defined unique wheel start positions that were set by adjusting the thumbwheel rings of each wheel. The wheel start positions were then sent in the clear to the receiving operator.

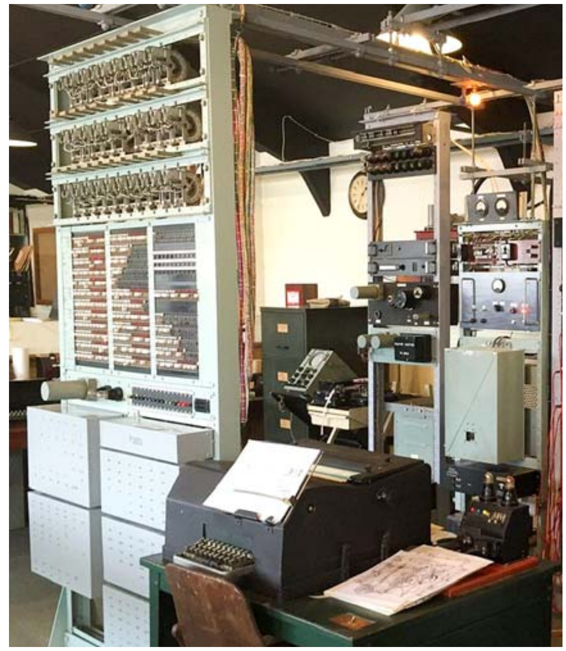
In July 1942 a group of cryptographers, led by Maj. Ralph Tester, decrypted Tunny messages using manual cryptographic methods. This group was called Testery. They exploited weaknesses in how the messages were identified, used common words and phrases (a.k.a cribs), did "in depth" analysis of long messages, and used a variety of linguistic and character frequency methods. They were able to break wheel pin patterns, start settings, and to decipher virtually all the messages from July to October 1942.

Maj. Ralph Tester, head of the Testery cryptography group.
Colossus Computer.com.

Other methods were sought to determine wheel pin patterns. In July 1942 Alan Turing spent a few weeks in the research group exploring techniques that might reveal statistical nuances of the pin patterns no matter how slight. He did have some success by comparing (XOR'ing) a character with its successor which cumulatively did reveal some statistical significance due to the presence of diphthongs (e.g. 'ei'), and double characters (e.g. 'ss', 'ee', et al) common in the German language. It is estimated in the German language, letters are repeated 20% of the time. Also the Lorenz operators often duplicated the Figures and Letters shift keys to make message less prone to selective fading because, should one of those shift characters be missed in the message, a good portion of the message could be garbled. They also repeated punctuation characters. Turing's approach of comparing (XOR'ing) successive characters was dubbed "Delta" and nicknamed Turingery.

During this period there was only an experimental Tunny link from Berlin to Athens. This link was closed in October 1942 and two new links began operation — Codfish (Berlin to Salonika), and Octopus (Berlin to Eastern Ukraine). With that change, the Germans revised message identification and corrected a weakness in setting pin patterns on Psi wheels. Both changes further slowed the decryption process using manual means. The search was on for more expedient methods and for mechanized devices.

## British Tunny Machine



A replica of the British Tunny on display at the British National Museum of Computing.

Since the design of the Lorenz system had been worked out, a machine, the British Tunny machine, was designed at Bletchley Park to be its functional equivalent and to emulate it. It was ordered April 1942 and built at Tommy Flowers' laboratory at the Post Office Research Station at Dollis Hill where the Enigma Bombe was built. The build team for this device included Sid Broadhurst, Bill Chandler, and Allen Coombs, a team who would build several code breaking devices including the Heath Robinson and Colossus. The first machine was delivered to Bletchley Park in June 1942. By May 1945, there were 13 British Tunny machines in service.

Tommy Flowers, machine designer and head of the Post Office Research Station at Dollis Hill. Wikipedia

The design used electro-mechanical technology including relays and stepping switches similar to that used in British telephone exchanges; input and output was via paper tape. Once the patterns of the 501 pins of the Chi, Psi, and motor wheels plus the start position of each wheel had been determined by manual methods, the machine was configured using plug boards with 501 plug points. The message was read from tape and decrypted. This machine didn't help in breaking wheel settings, but greatly expedited the decryption of messages once those settings had been found.

## Developing Statistical Wheel Breaking Methods

Beginning in December 1942, another group under the direction of Max Newman focused on using statistical cryptological methods to discover improved methods for determining wheel patterns and start positions. This group was called the Newmanry and included Bill Tutte who provided the next breakthrough.

Although the Germans intended there be minimal to no statistical significance in any one bit channel, Bill Tutte theorized then demonstrated that statistical significance could be found when considering two bit channels of the encrypted message together. He did this by extending Turing's delta approach to compare (XOR) successive bits of each channel 1 & 2, which are then XOR'ed together, a technique called "Double Delta." Double Delta measures the change in a pair of bit streams. The statistical significance appears in the count of occurrences where the XOR of the two channels is '0' due to repeated characters or characteristics of the German language. Instead of the values of the delta XORs being 50/50 as in the individual Chi, Psi, and motor wheels, the statistic is, on average, 57% in favor of 'spaces' over 'marks'. 57% may not seem like much difference from 50%, but for long messages was significant. This technique was critically important as it was the basis for further advances in decryption and enabled mechanized approaches.

Tutte's second insight was that the irregular motion of the Psi wheels did not have the 50/50 randomness that the Germans had intended. In fact, Tutte showed that since the motor wheel pin settings were set to 50/50, then mathematically the combined delta effect of the Psi and motor wheels resulted in greater frequency that Psi wheels were stationary and its bit pattern remained unchanged. Thus, on average the Psi wheels had a null

Max Newman, head of the Newmanry cryptography group. Wikipedia.

William Tutte, made important statistical advances in breaking the Lorenz cipher. University St Andrews.

effect on the encryption 70% of the time meaning that, on average, the encryption depended only on the Chi wheels 70% of the time.

The focus of the cryptographers was to then determine the pin settings of the Chi wheels. They had the best results just focusing on the first two bit channels using Double Delta. They developed techniques determining the most promising Chi pin settings using a method called Rectangling where the results of the Double Delta were entered into a 31 x 41 matrix (the number of pins of the Chi channel 1 & 2 wheels) in order. Since the matrix had only 1271 cells and messages were much longer, the Double Delta values continued to be iteratively entered into the matrix until the values for the entire message were processed. The sums of the Double Delta values were accumulated for each cell. At the end of the run, the pattern of Double Delta values indicated the settings for the Chi wheel that were most probable. Once the first two bit channels were determined, they used the same technique to analyze the remaining three Chi channels. Once complete, the pin patterns of the Chi wheel would be known and the Chi portion of the encryption removed. This process was dubbed "de-Chi'ing." They would then unravel the remaining impact of the Psi/motor wheels. The rectangle method could be computationally intensive as there were 41x31=1271 possible pin settings to consider for the first two Chi wheels. For a 10,000 character message, there would be 12,170,000 calculations, too many to do by hand.

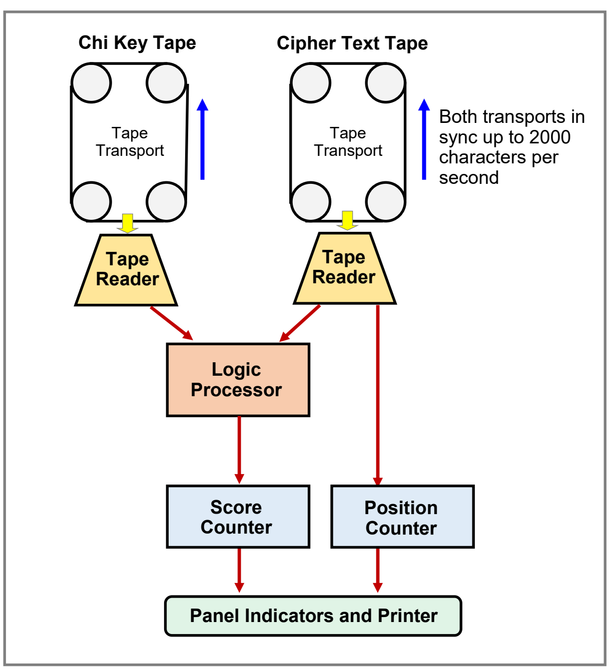
Chi wheel start positions could be determined with an XOR analysis of the first two bit channels of the encrypted message with those of the de-Chi tape and a sum of the XOR results would be tabulated into a score and the respective start position recorded. This would be done for all possible 1271 start positions. At the end of the analysis, the start position with the greatest score would be the most probable. This also involved many calculations and was more efficiently done by mechanical means.

This is a brief sketch of the techniques. For more details, see the book *From Fish to Colossus* listed in the Sources section at the end of this article.

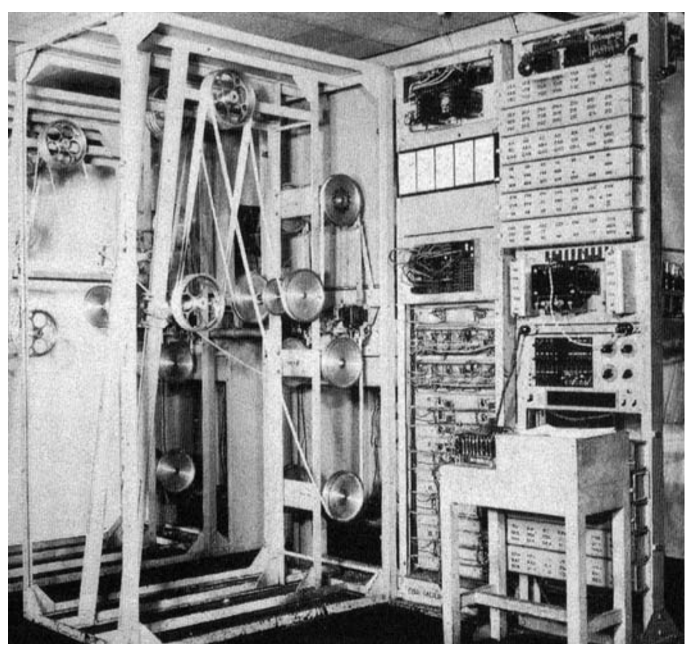
## Heath Robinson

To help determine Chi start positions, the Heath Robinson machine was conceptualized by Max Newman and ordered in January 1943 It was built by Tommy Flowers at the Research Laboratory in the Post Office Research Station at Dollis Hill and delivered in June of 1943. The Heath Robinson was named after a British WWI cartoonist who devised ingenious complicated machines to solve simple problems, similar to Rube Goldberg in America.

The Heath Robinson implemented the Double Delta algorithm. It had two tape readers that held long tape loops. The first loop was the encoded message and the second loop was the Chi key. Driven from the sprockets on the same shaft,




Heath Robinson block diagram. The logic processor implemented Double Delta algorithm with XOR and phase shift circuits. Adapted from: *From Fish to Colossus.*



The Heath Robinson successor Old Robinson. The two were virtually identical. A replica is on display at the British National Museum of Computing. Source: *Colossus - The Secrets of Bletchley Park's Code Breaking Computers*; British Archive Images Library.

the two tapes are read synchronously using photo electric cells at a rate up to 2000 characters per second. The Chi key tape was pre-punched with the 1271 possible combinations of the first two bit channels. This pattern was repeated for the length of the message tape plus one; the Chi key tape was made one character longer than the message tape so that, when the message tape repeated, the Chi key tape would have advanced one character providing a different set of comparisons on the next iteration. The Robinson machine ran the loops repeatedly until all the comparisons had been made. Robinson machines were configured and operated by W.R.N.S (Women's Royal Navy Service) staff.

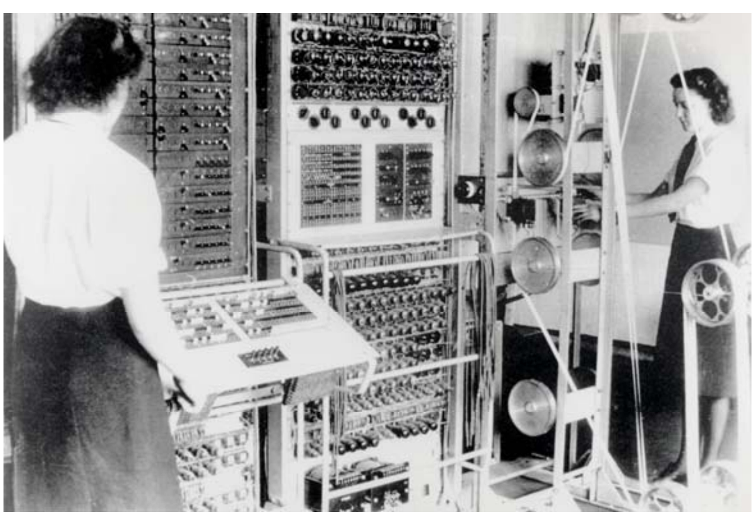
As with the manual Double Delta method, only the first two bit channels were processed by XOR'ing the successive bits of each channel one and two. The XOR's were done in the logic processor using vacuum tube phase shifters; a 0° shift if the XOR was 0 and a 180° shift if the XOR was 1. Using the phase shift approach, it was straight forward to cascade XOR circuits and add the results for counting and scoring. The counters were designed by Winn-Williams using gas-filled thyratrons. At the end of each message processed, if score count for that message exceeded a preset amount, the score and corresponding position on the Chi key tape was displayed on the front panel and, for later Robinson models, on a printer. At the end of the run, the result with the greatest score indicated the most likely correct value for the Chi wheels. Cryptanalysts then confirmed the result and determined the values for remaining three bit channels on the Chi wheel. The message would then be de-Chi'ed. For more design details and schematics, see the book *From Fish to Colossus* listed in the Sources section at the end of this article.

The Heath Robinson greatly expedited this process but was not without its faults. Because it relied on electro-mechanical technology, its processing speed was relatively slow. The tape transport also proved to be unreliable, and it was difficult to keep tapes in sync. It also used indicator lights only to show the score; it was a source of error displayed only briefly until the next score was displayed, and the operator had to be quick to capture it. Later Robinson included the ability to print scores along with respective Chi start values. The Old Robinson was the immediate successor to the Heath Robinson and addressed several of these issues.

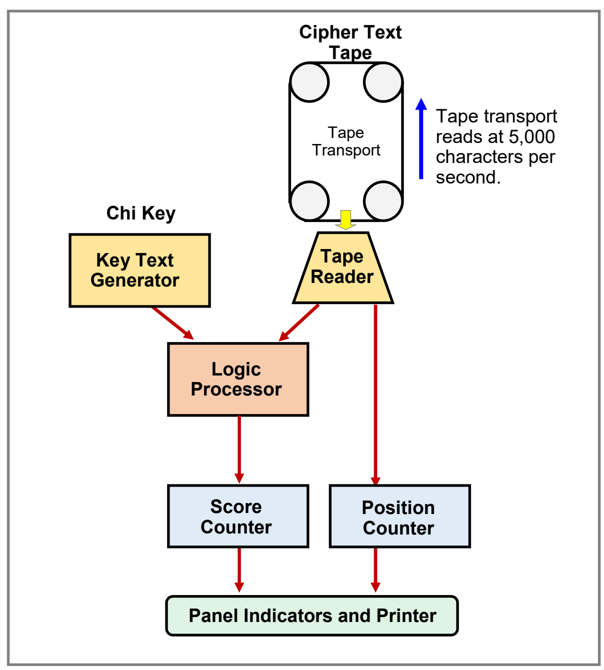
## Colossus

Because there were fundamental limitations and reliability problems with Robinson machines inherent in its design, Max Newman met with Tommy Flowers to discuss more robust alternative designs. Tommy Flowers proposed a novel approach using initially 1,500 vacuum tubes (later models would use 2,400). There was much skepticism in using vacuum tubes as they were believed to be unreliable from experience of their use on bombers. Flowers knew it could be done and went ahead with the build; he went into debt purchasing many of the parts himself. The project began February 1943 and the first Colossus was operational January 1944.

At a basic level, Colossus performed much the same functions as the Robinson machines; its high level block diagram closely resembles that of the Robinson.



W.R.N.S staff operating a Colossus. The lady on the left is configuring the Rectangling panel. The lady on the right is mounting a tape. Wikipedia.




Colossus block diagram. Implements the same functionality as the Robinson and much, much more because it can be reconfigured/programmed. The Key Text Generator produces the Chi stream. Adapted from: *From Fish to Colossus*.

Unlike the Robinson machines, the Colossus was designed to be highly configurable giving it much more flexibility in tackling a wide variety of computational algorithms and tasks. Its ability to be configured, patched, and programmed, coupled with its digital design, makes it arguably the first digital computer predating the ENIAC by two years.

Tommy Flowers designed many innovations into Colossus:

A faster tape transport, the 2,000 characters/second of the Robinson was increased to 5,000 characters/second on Colossus;

Single machine clock derived from the speed of the tape reader;

The generation of the Chi key text using a Thyratron ring replacing the second Robinson tape reader;

Parallel calculation circuits were employed to improve computation speed and throughput, 100 binary operations per second which represents 2.5 million Boolean operations per second;

Electronic components were designed to be modular and standard throughout the machine;

All logic would be implemented with DC voltages using a two-wire pair, now known as two-rail logic;

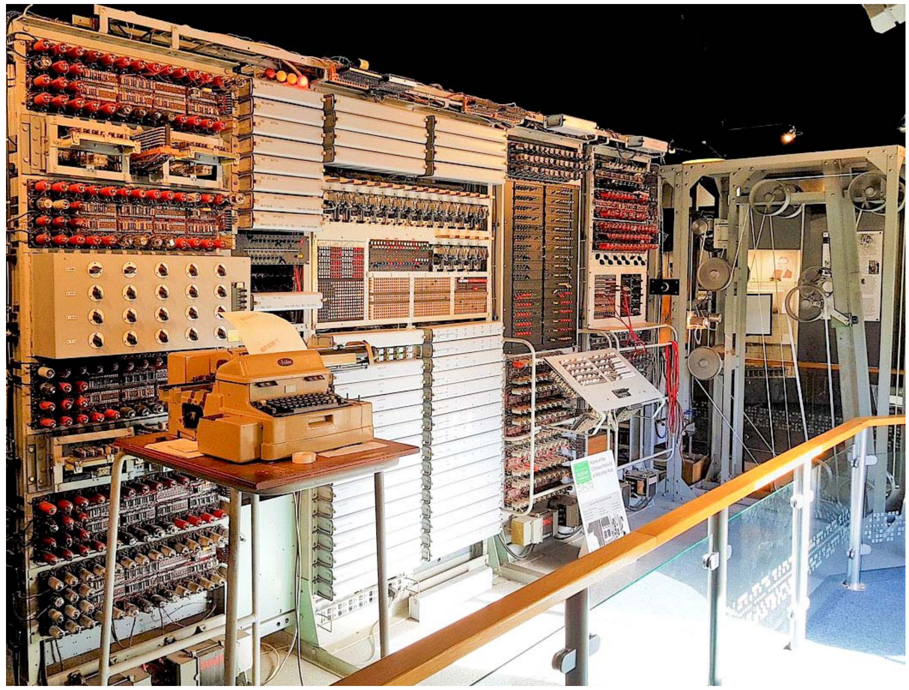
Output buffering was also done in a standard way thus simplifying design of stage interconnections;

XOR circuitry used voltage level logic instead of the complex phase logic of the Robinson machines;

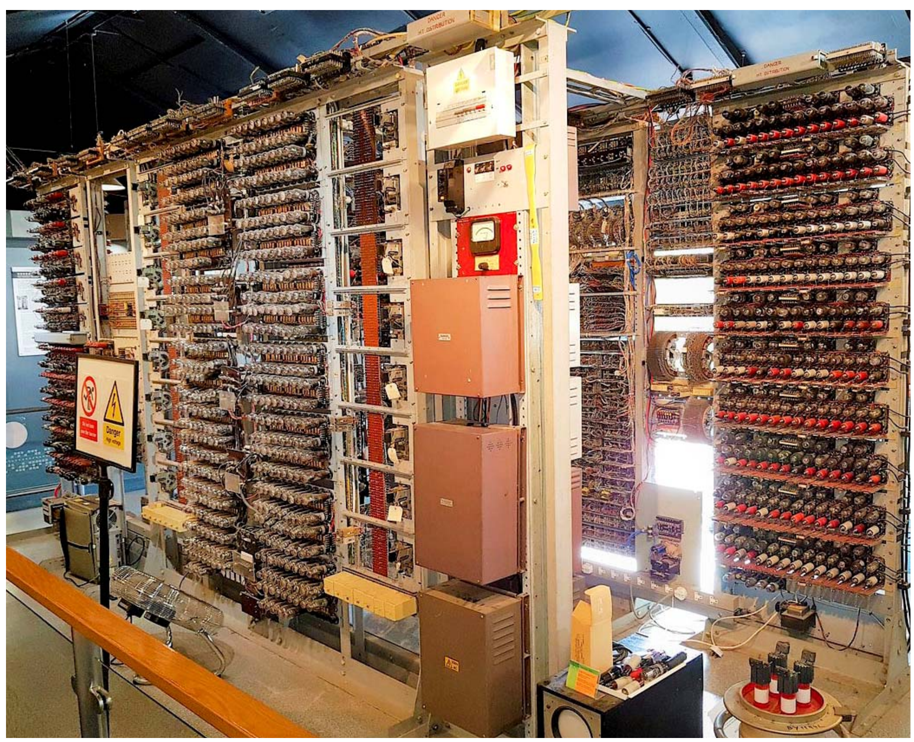
First recorded use of shift registers and systolic arrays;

All output was printed automatically instead of just displayed;

Colossus vacuum tube circuitry proved to be extremely reliable.

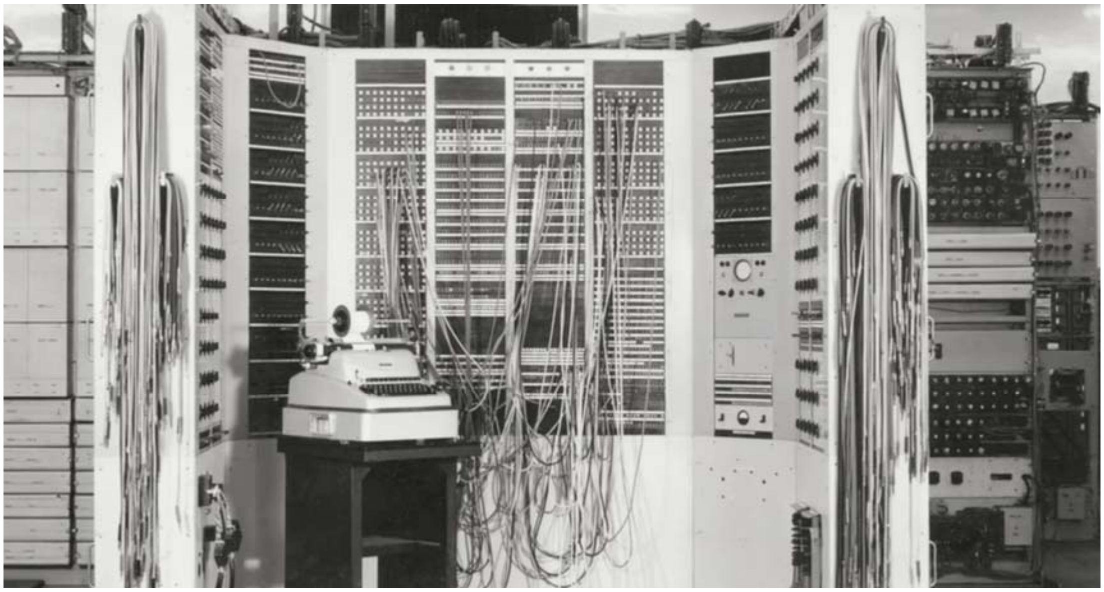


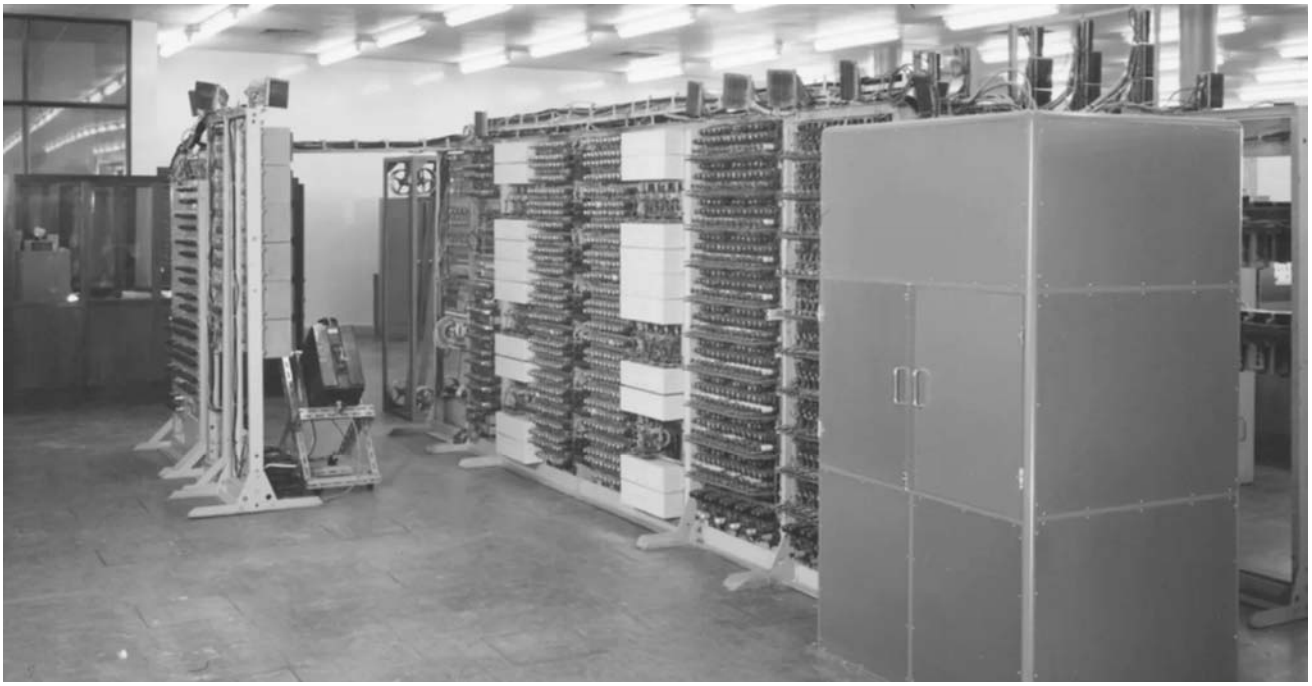
Front view of the Colossus reproduction on display at the British National Museum of Computing. Paper tape transport is on the right. The basic structure is a series of racks holding tube arrays and configuration switching for the various functions. This reproduction was built in the early 1990s by a team led by Tony Sale. It incorporated the original Colossus designs. Officially all the original design and operational documentation had been destroyed just after the War. In interviews with engineers who built the original, the team was given enough of their personal documents and knowledge to proceed. Much of the operational methods and details came from records in America obtained from the Freedom of Information Act. This reproduction Colossus first became operational on June 6th 1996 and was fully competed in 2007.



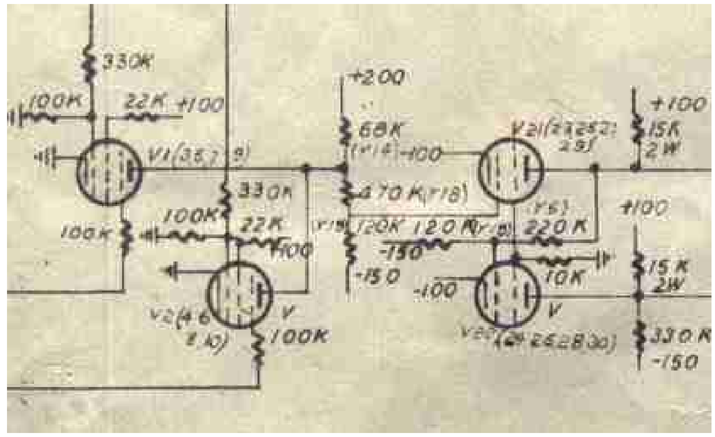
Rear view of the Colossus reproduction. This shows the backside of the front rack and the second rack. Again full of tube arrays and wire patch panels. The front side of the rear rack can't be seen but is full of more tube arrays and configuration panels.

On January 18, 2024, the British GCHQ finally released never-before-seen information and photographs about the Colossus including these images which are of a system that was in use until the early 1960s. The photos were taken in 1963.
Source: British GCHQ website.





Donald Michie, a gifted cryptanalyst who devised the Rectangling attachment for Colossus enabling the breaking of Chi wheel settings.  He later had a distinguished career in computer science and was a pioneer in artificial intelligence.  Wikipedia.




Colossus XOR circuit, drawn by Tony Sale.  This XOR circuit used voltage level logic.  Tony Sale was responsible for building the reproduction Colossus at the British National Museum of Computing. Codesandciphers.org.UK

For more design details and schematics, see the book *From Fish to Colossus* and the website Codesandciphers.org.UK.

One important enhancement devised by a cryptanalyst in the Newmanry, Donald Michie, enabled the Colossus to solve Rectangling.  With that, Colossus could then be used to break Chi key pin patterns.  This became essential in August 1944, shortly after D-Day, when the Germans changed from monthly key settings to daily key settings.  Thus, the 501 pin settings of the Chi and Psi wheels changed every day.  The Colossus provided the speed and computational capability to continue to break these keys without missing a beat.  But if Colossus hadn't been created or didn't have this wheel breaking capability, the situation would have been disastrous.

Their importance can't be overstated.  An example, Colossi decryptions provided vital information to Eisenhower and Montgomery prior to D-Day.  They showed that Hitler had believed the allied deception that attacks would be coming from Pas de Calais, which caused him to withhold Panzer divisions in preparation for that invasion instead of sending them to Normandie.  After D-Day, to increase the radio transmission of Tunny messages, allied forces bombed and strafed teleprinter and telephone landlines in Northern France forcing the Germans to use radio links.  The volume of Tunny traffic and the amount of decryptions increased greatly.

By May 1945, there were thirteen Colossi in operation at several sites in England.  Newmanry had a staff of 325 W.R.N.S who primarily did the configuration and operated the Colossi 24 hours a day, seven days a week.   Total staff supporting the Colossus effort was 550.  There was 600 additional staff receiving and transcribing radio messages at Knockholt/Biggin Hill.

After the war to preserve the secret, under direction from Winston Churchill, all the Colossi were destroyed except two which continued in service for several more years providing aide in decryption of other traffic of interest. This secret remained classified and was not revealed until 2000.  By comparison, Enigma became publicly known in the 1970s.

Colossus was critical to the outcome of the war.  It reduced the time to break Lorenz messages from weeks to hours.  It is estimated that 63 million characters of text were deciphered.  It was invaluable as they were the communications of the German High Command.  It has been estimated that the codebreaking at Bletchley Park shortened the war by two years.

## Sources


Davies, Donald W., "The Lorenz SZ42 Cipher Machine"; Cryptologia, January 1995, Volume XIX, No. 1

Copland, Jack, et al, *Colossus - The Secrets of Bletchley Park's Codebreaking Computers*, Oxford Press, 2006 **Included in this edited compilation are articles written by those who were there and contributed to the breaking of the Tunny messages, and to the design and use of devices.**

Cragon, Harvey G; *From Fish to Colossus,* Cragon Books, Dallas, Texas; 2003  **This is an excellent summary of the achievements and methods in breaking the Lorenz cipher system and resulting Tunny messages.  It includes many design details of machines.  This would be the place to start for a more in depth detail.**

Good, Michie, Timms, *Breaking Teleprinter Ciphers At Bletchley Park - General Report on Tunny With Emphasis on Statistical Methods (1945);* Editors: James A Ree, Whitfield Diffle, J.V. Field; IEEE Press & Wiley, 2015  **This is the first hand primary source and authority for information related to the efforts to decode Tunny and the design and build of decryption devices including the Heath Robinson and Colossus computer.**

Sale, Tony; *Colossus 1943-1996*; M&M Baldwin, 2014.  **Much of Tony Sale's information is also on Codesandciphers.org.UK**

Shore, Chris, YouTube presentation *Colossus - The Greatest Secret in the History of Computing* at the Centre of Computing History, 2020.

Wikipedia.com - various topics including Teleprinter, Baudot Code, Breaking the Lorenz Cipher, Donald Michie ◊

# CHRS Holiday Luncheon