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20 Years of Change

EVERYTHING OLD IS *NEW* AGAIN

In the rather world-weary way of the French people he so admired, Humphrey Bogart's "Rick" in *Casablanca* would have said, "en plus ça change, en plus le meme chose." Literally, that means "The more things change, the more the same choice."

Bogie's observation applies to today's burgeoning world of telecommunications. Most of today's mind-numbing volume and speed of telecommunications really uses, at its core, the principles developed a century ago. What's made the explosive difference are the vast strides in micro miniaturization, which in turn, has enabled the reductions in space, weight, power, cost and heat that few of us could imagine even 20 years ago.

In turn, those changes have made enormous amounts of digital signal processing possible. So much so, that our long-standing need for linear processes, and linear transmission channels for telecommunications, has all but disappeared. Today, we have receivers for every transport medium that can reconstitute an almost perfect reproduction of the input from a received signal that would often be unrecognizable by classic linear methods.

Because so much of the processing can now be done with software, many people think these miracles were recent innovations. That's largely because most of the old linear processing was obscured from general public view in places like "The Phone Building" or in gargantuan transmitter plants located by necessity at remote sites. The fact is that most of the basic principles of telecommunications were first established even before the era of electronics. Indeed, some date to times before electricity itself was even understood or harnessed in any way. Consider a few:

Binary Transmission

Who knows how far back into human history binary signaling dates? We have credible evidence that the Picts of Scotland used smoke signals to warn of impending Roman attacks millennia before Western explorers found the Plains Indians using them. It may be more ancient than the Greek heliograph that was still being used by the army of George Custer. And of the antiquity of jungle drums? Who would even hazard a guess? When we finally began to get a handle on electricity, almost every electrical attempt and success from the 17th through 19th centuries was in building a binary telegraph – ultimately encoding everything in ones and zeroes and sending the bits serially, then decoding the information at the receiver.

Time Division Multiplexing (TDM)

Few people—even many who labored in the telephone industry for an entire career and have used the term daily since the 1960s introduction of digital telephone carrier—know that TDM was actually fielded before Bell's telephone. The root of TDM is directly traceable to Jean-Marie Emile Baudot, an engineer in the French government telegraph system. Baudot used his Time Division Multiplex as a means of transmitting four sets of keyboard telegraph signals over a single line in 1974. In doing so, he had to devise the coding system and isosochronous code we call the "Baudot Code," which still finds much use worldwide. That method, with little variation, remained in use under various names, but always using rotating mechanical commutators, for nearly a century right into the 1970s.

Circuit Integrity and Assurance — The First Protocol

Binary signals, while having several sets of names, only have two states: On or Off, Mark or Space, one or zero, current or no current, and so on. Even Marshal Dillon and his cronies in Dodge City knew the value of this principle. Whenever they socialized at the telegraph office in the railroad station, they, like the telegrapher, knew that the idle telegraph line had current flowing at all times, which was a constant "On" or "Marking" condition. They could be engaged in conversation, but when the telegraph sounder clicked and dropped open from a loss of current, or "Zero" state, they knew one of two things had happened. Either the circuit was broken and they were isolated from the world, or a message was about to begin. They timed for a while. If no message started, they assumed the line was broken and sent out a repair party.

To this very day, with rare exception, the standards for digital transmission paths have them set in a continuous "1" state when idle. A change to "0" is timed for the start of a transmission. If no transmission follows, the system alarms a perceived loss of its transmission path, and a repair party is dispatched.

Radio Test Ranges and Boresight Receivers

In June 1901, Marconi was conducting demo after demo attempting to show a skeptical world that wireless signals could indeed travel beyond the optical horizon. His marine shore station at Crookhaven, Ireland, immediately adjacent to Ireland's most southwesterly point of land, Mizen Head, was reporting receiving signals from the Marconi site at Poldhu, England. Crookhaven happens to lie on an azimuth very close to that of the northeastern coast of North America from Poldhu.

Marconi traveled to Poldhu specifically to satisfy himself that indeed, Poldhu produced reliable signals to Crookhaven, some 225 miles away. Finding reliable transmission did exist to the end of his available "test range," Marconi decided to proceed with the

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famous transatlantic effort that occurred in December 1901. The Crookhaven building is today a summer seashore house. Neither its residents nor the thousands of summer tourists who flock to the nearby town are likely to know the historic decision that was made there.

Pulse Code Modulation

Alec H. Reeves, originally with a part of the English Western Electric Company that became Standard Telephone Laboratories, was one of England's most prolific founders of core technology. He conceived the notion of sampling an analog waveform at twice its highest frequency and then assigned a numeric value to each sample for encoded transmission. He received French, British and U.S. patents for his invention in rapid succession. Reeves actually demonstrated what amounted to a PCM "channel bank" for telephone systems in 1938, but its vacuum tube and relay technology were so large, power-hungry and expensive that Reeves' invention sat fallow until the happenstance of the transistor made it practical. Constructing a telephone channel bank and the T-1 carrier system became one of the first uses for the transistor. Today, "T-1's" and "channel banks" and their descendants like MPEG Audio Codec, G.711 a-law and Mu-law PCM, G.722, G. 726, G.727 and G. 728 PCM and ADPCM are ubiquitous in ATM Adaptation Layers 0 and 1, as is digital PCM recording of every sort of sound and picture using NICAM methods.

Magnetic Recording

Following up on a suggestion by American Oberlin Smith published in 1888, Danish telephone engineer Valdemar Poulsen obtained a patent in 1892 for his "Telegraphone" recording machine, using a steel tape. In its early years, lacking amplification, the Telegraphone was useful primarily only for recording telegraph pulses. Poulsen's patent, however, stated its purpose was to record messages for telephone subscribers when they were not able to answer a call, thus showing that Poulsen's intent was to provide the world's first "voicemail" in the Gay Nineties. Germans actually developed the process for manufacturing magnetic-coated tape (at first paper-backed). This technology was discovered by the Americans in Germany at the end of WWII and taken to the United States, where magnetic recording reached the level of practical use it has today.

Fiber Optic Transmission

Glass fibers had been drawn in Roman times, and by the 1840s, light rays were being guided for entertainment purposes along water jets and glass rods. The most notable early demonstration was as a stage effect in the 1853 production of "Doctor Faust" by the Paris Opera. However, it was Alexander Graham Bell who, finding that copper wire had severe constraints in transporting his new telephone, came up with using light to transmit speech through space. Bell patented his Photophone in 1880. In Bell's own words, the photophone was "the greatest invention I have ever made; greater than the telephone." It revealed the principle upon which today's laser and fiber optic communication systems are founded. However, it would take the development of several modern technologies to realize that fully. In 1880, the many bugbears of atmospheric attenuation and issues of crosstalk led telecommunications development along the path of copper wire and the soon-to-be-invented wireless radio. Bell let the Photophone lie fallow. Bell ultimately donated his prototypes to the Smithsonian's museums.

In the meantime, light for illuminating dark places continued to seek new technologies to guide it. Early mechanical television systems in both England (Baird) and the U.S. (Jenkins) used glass rod bundles to conduct macro-sized pixels from individual lamps to their viewing surfaces, since they had no suitable cathode-ray tube as yet. But guided illumination for medical inspection inside bodies was driving its own development, and by 1939, the medical community had illuminated Lucite tongue depressors. Medical desires to bring images back from endoscopes within the human body kept driving wants for flexible glass or plastic rods that could not only transmit light, but also carry useful images back from deep within the body. That spurred materials developers by 1951 to adopt the notion of waveguide-like flexible rods with two indices of refraction, the outer layer effectively containing the light within the glass fiber.

Medical development continued apace, but the absolute transmission losses frustrated telecommunications consideration of guided optical transport. Telecommunications developers proceeded down the line of millimeter-wavelength electromagnetic waveguide transmission. Bell Labs announced its commitment to fielding its WT4 millimeter waveguide transmission system because there was no credible future alternative, and the Bell System desire to advance telephony to the PicturePhone requiring 1.5 megahertz of analog bandwidth per line was pressing heavily.

At that point, optical transmission needed two primary developments. First was optical fiber that had losses low enough to be practical. Alec Reeves and his group at England's Standard Telephones Laboratories suggested that if fiber losses could be reduced below 20 db per kilometer, practical transport systems could be realized, at least for short-haul within cities. The STL crew took on its own sort of missionary project to the world stirring interest in the concept. In parallel, the US Army Signal Corps increased its interest in finding an optical alternative for secure, interference-free transmission and backed that interest with development money for US manufacturers. By 1968, glass fibers of sufficient purity were becoming available enough to consider seriously the second need a real priority for telecommunications.

That second need was a light source of sufficient strength, stability and reliability for long-term operation. The source was laser diodes, first demonstrated in 1960. It took another 17 years to develop lasers of sufficient life and long enough wavelength (gallium arsenide) to achieve a practical marriage with fiber waveguide for telecommunications transmission use.

Finally, by 1980, a full century after Alexander Graham Bell conceived of telecommunications over lightwaves, physics and materials science caught up with the concept.

Everything Old is New Again

So, in the words of the once-popular song, we can see evidence that the basic concepts and processes behind what we are so busily spreading across the entire globe have really been with us for a century or so. Perhaps were our schools to teach some of this history, the public would become more intelligent users of it and overcome the instant marketplace glut of unused capacity that is plaguing the economy. Ω

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