RTT TECHNOLOGY TOPIC
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The Armstrongs

This is the story of three Armstrongs, Edwin, Louis and Neil, not directly related, but each of them involved as inventors or users of FM modulation. We are going to demonstrate why their life stories are relevant to contemporary 4G and 5G terrestrial broadband and satellite delivery economics.

100 years ago, as World War One was finally ending, Edwin Armstrong was engaged in litigation with Lee De Forrest over patent rights for **regenerative circuits**.

Armstrong's original patent had been filed in 1912 and described how taking some of the output from an amplifying device and feeding it back into the input of the device improved amplification by several orders of magnitude. By increasing the amount of feedback, the device could be made to oscillate and could therefore generate a carrier wave. Applying a similar feedback loop to the associated tuned circuit improved receive sensitivity and selectivity.

These regenerative radio systems came into common use from 1915 onwards but produced large amounts of interference when oscillating and were gradually replaced by Armstrong's second big innovation, **the superhet receiver** in which the incoming RF signal was mixed with a locally generated signal at a different frequency to produce a lower intermediate frequency which could be more easily amplified and filtered. The patent for the superhet transceiver was issued in 1919.

In 1928 Armstrong began research on wide band **FM modulation** with patents issued in 1933 describing how the system could potentially deliver improved filtering, increased bandwidth and longer range with a threshold effect that would produce a higher signal to noise ratio in relatively strong signal conditions. The trade-off was between in band efficiency and out of band interference, a physical reality that generations of regulators have either misunderstood or ignored.

In June 1936 Armstrong demonstrated his FM system to the FCC by playing a Jazz recording on AM radio then switching to FM. A press correspondent commented that if the audience of 500 engineers had shut their eyes they could have believed the Jazz band was in the same room.

It would be nice to think (though impossible to verify) that that recording might have been by Louis Armstrong. The trumpet after all is a classical resonant amplifier using the harmonic series to deliver (in Armstrong's case) a three octave range. Armstrong (Louis not Edwin) owed much of his international success to the power of broadcast radio. He hosted his first radio show in 1937.

However it was going to take at least twenty years before FM radio broadcasting became widely adopted and comparative quality only became an issue when long playing vinyl was introduced yielding a clean undistorted 20 KHz of audio response in up market home audio systems.

Edwin Armstrong never lived to see this having committed suicide in 1954 worn down by litigation and mortified by having hit his wife with a poker in a fit of frustration (she was not impressed).

In the meantime FM had been used by the US armed forces in the Second World War (harder to jam than AM systems) and less extensively in doppler radar and then notably by another Armstrong (Neil), to communicate with Earth during the moon landing on July 20 1969. FM radios including broadcast receivers and two radios remain in widespread use today. Never the less it is a timely reminder to consider why FM broadcasting took so long to become established.

The adoption barriers can be summarised as a wide established base of AM home receivers combined with improvements in AM broadcast technology and available bandwidth. In 1937 for example, introduction of the APEX 'high fidelity' band in the US with 75 broadcasting frequencies from 41.02 to 43.98 MHz with 40 KHz rather than 10 KHz channel separation allowed a frequency response from 20Hz to 17 KHz.

This was significantly better than the 10 inch 78 rpm shellac records available at the time, the best of which were Parlophone 'full frequency' FF pressings limited to an upper range of 10 KHz. The consumer experience FM quality gain was therefore potentially useful but not compelling.

In terms of broadcast range gain, Armstrong (Edwin not Louis) demonstrated that a 40 kilowatt FM broadcast at 42.8 MHz would go at least as far (160 kilometres) as a 50 kilowatt AM station but the sunk cost in existing AM stations suppressed investment sentiment. Issues over patent rights would not have helped either.

The Second World War then intervened but in the late 1940's FM radio suffered another setback when the FCC decreed that FM would introduce potential interference into the 40 MHz AM bands and that FM should be deployed into 100 hundred channels between 88 and 108 MHz (where many FM stations are still broadcasting). This decision implied a significant increase in market entry costs for prospective FM radio stations coupled to the additional technical complexity and cost of producing receivers capable of working at higher frequencies.

Following his death, Edwin's wife Marion settled the litigation with RCA with RCA paying 'approximately $1 million dollars' for the patent rights to FM but it was to take another ten years before FM became ubiquitous in the US helped by the introduction of stereo broadcasting.

The moral of the tale is that it is hard for a lone inventor particularly an inventor with a stubborn streak to consistently win litigation battles. The royalty income required to fight on going court cases can often take years to accrue due to regulatory barriers, the motivation to protect vested interest in the AM broadcasting industry and sunk investment by broadcasters in transmitter hardware and home owners in broadcast receivers. Additionally while a few people are prepared to pay a premium for an enhanced user experience, the majority just expect better at the same or lower price.

Translating this into the last thirty years of cellular radio, we can observe similar market and commercial dynamics, adoption enablers and barriers and associated deployment and profitability time scales.

Some of the crucial early patent rights in digital radio, for example in digital codecs and channel coding and modulation were successfully parlayed into sustained commercial success.

Linkabit is probably one of the best examples with Irwin Jacobs and Andrew Viterbi from 1983 onwards executing a text book example of how to use clever maths to found a company, Qualcomm, now worth $100 billion dollars making Marion's million seem tame by comparison.

https://www.sandiegohistory.org/journal/v55-1/pdf/v55-1west.pdf

Essentially the essence of success can be summarised as providing an improved user experience (more bandwidth, longer battery life, more services) with products (smart phones rather than mahogany radio receivers) that consumers are proud to own at a price they can afford.

If the enabling technologies can at least have been partially paid for by defence spending (Linkabit satellite modems for example) then that all adds to the equation though managing and influencing regulatory and competition policy is also critical to success.

All of which leads us to the ongoing conundrum of the satellite industry and 4G and 5G community.

Neil Armstrong and Buzz Aldrin produced the most compelling TV programme I have ever watched (the moon landing 50 years ago) with the recent film First Man providing a contemporary celebration of the achievement.

In 1973 the total cost of the Apollo programme was reported to Congress as $25.4 billion.

Today this seems like small change in a world where the Fangs, Facebook, Amazon, Apple, Netflix and Alphabet, the owner of Google have either exceeded (Apple and Amazon) or are approaching individual market values of a trillion dollars. These valuations are based on relatively low earnings multiples. Apple is trading at 14 times earnings. At the height of the Dot Com boom in 1999, Cisco was trading at well over 100 times its earnings. Companies such as Amazon have highly successful cloud computing divisions with profits growing at over 1000 per cent per year so these are profit based rather than speculative valuations.

Over the next ten years, Ten cent and Ali Baba might make these numbers look conservative.

So the question is can individuals like Elon Musk, Jeff Bezos and Richard Branson and their Chinese and Indian and Latin American and African equivalents and the corporate global entities that they own produce a new space based connectivity business model that changes the world?

Or will it be space based defence spending (Space Force as the fourth fighting force?) that drives future technology innovation.

Commentators assert that technology is changing faster than ever before. There is no evidence to support this. It can however be stated unequivocally that technology progress is a cumulative process that delivers occasional memorable moments.

It was cumulative technology progress that made possible that one ‘small step for man large step for mankind ‘(Armstrong, Neil, 1969).

It is cumulative technology progress that makes it possible to send spacecraft to the sun and men to Mars. Fly me to the Sun and let me play among the stars; Let me see what spring is like on Jupiter or Mars (Sinatra, Frank 1954 with apologies to Bart Howard).

Back on earth, cumulative technology progress has shaped the ‘wonderful world’ in which we live where for the moment at least the trees remain green and the skies remain blue (Armstrong, Louis, 1967).

Let’s try to keep it that way.

CW Wireless Heritage Event at the Science Museum this Friday (October 5th)

We are delighted that Matthew Stuttard from Airbus Defence and Advanced Space Systems will be giving a talk on the solar orbiter project at the CW Wireless Heritage event on Friday this week (October 5th) **Sixty Years of Satellites- From Sputnik to Space X**

A wait list is in operation for the event, but if you are interested please register and we will see what we can do to accommodate you.
https://www.cambridgewireless.co.uk/events/sixty-years-satellites-sputnik-space-x/

Ends

New Book - 5G and Satellite Spectrum, Standards and Scale

Our new book, **5G and satellite spectrum, standards and scale** is now available from Artech House and will be available for sale at the October 5th event though you can also order a copy on line using the code VAR25 to give you a 25% discount.

http://uk.artechhouse.com/5G-and-Satellite-Spectrum-Standards-and-Scale-P1935.aspx

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RTT, and **The Mobile World** are presently working on research and forecasting projects in the mobile broadband, public safety radio, satellite and broadcasting industry and related copper, cable and fibre delivery options.

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