Improving the Noise Performance of Communication Systems- 1920s to early 1930s

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Post- WWII

- Advances due to Radar R&D
- Beginning of Communication/InformationTheories
- Emphasis on reception, Signals in Noise

This paper:

How did it all begin?

Paper Summary

- Introduction and overview
- Static characterization/reduction, radio systems
- John Carson and noise performance, telephony
- Armstrong and wideband FM

Circa 1920: How to reduce “noise”?

- Radio- Problems with “static”, i.e.,
  “atmospherics”

- Wired telephony- vacuum-tube noise, i.e.,
  “shot noise”

Walter Schottky, 1918

Described “fluctuation noise” in electronic circuits:

- “Warmeffekt”- resistive noise (“thermal noise”)
- “Shot noise”- variations, current flow: random charge emission

Much more significant at the time

Telephone Engineers- Fluctuation Noise Characterization

- J. B. Johnson, AT&T,

  early 1920s, expts, shot noise

  1928, expts, thermal noise-

  more fundamental

- Harry Nyquist, Bell Labs,

  1928, theoretical study/explanation,

  thermal noise

Radio Systems- ”static” the problem

- 1920s- Much activity explaining, characterizing static- “atmospherics”: from Sun, due to storms…

  Note: only passing mention in radio literature on fluctuation noise

- Measurements show variation with time of day, season, frequency of transmission, locations of transmitters, receivers

  Note: static decreases with frequency

To improve static performance:

- Need to maximize “signal-to-static ratio”
- Use appropriate carrier frequency (possibly vary with time of day/season):

  “*very little trouble*”, short-wave band

  (3-30 MHz)
- Use directional antennas

Antennas to reduce static

- 1919, Multiple receiving antennas,
  Marconi Corp.

- 1920, G. W. Pickard, Directional loop antenna (“*pioneering work*”)

- 1923, Beverage “wave antenna”, RCA Corp.

Telephone activity: *John R. Carson, AT&T*

- Carson joined AT&T, 1914

  BS, Princeton, 1907; EE, 1909; MS, 1912

  inventor, single-sideband AM, 1915;

  analysis, FM bandwidth, 1922
- Noise performance papers, 1923-1925:

  initially on static, then circuit (shot) noise

Carson's Contributions, 1923 (with Otto Zobel)

- Provide understanding, noise, electrical systems

  Specific example: "wave filter"

  (Frequency-selective network)
- Noise model: shot noise-like

  (individual, random impressed forces)
- Use "selective figure of merit":

"*statistical signal-to-random interference ratio*"

(related to signal-to-noise ratio, SNR)

Carson/Zobel, 1923 (cont)

- Define noise *frequency spectrum:*
  use Fourier Transform (new at the time)

- Describe *band-limited white noise*:
  "all frequencies equally probable"

- Compare figure of merit, various selective circuits
  Get "general deductions of practical importance"

- Approach unique at the time:
  use simple models of circuits, find SNR improvement

Frequency approach controversial

Does Fourier representation of *random impulses* exist?

Thornton Fry, AT&T colleague,1925: *No!*
Schottky (1926), GE workers (1925): *Yes!*

By 1928, 1929- Approach commonly adopted
(Ex: Johnson and Nyquist, 1928, use frequency analysis to study thermal noise)

Carson contributions, 1924-25

- Shows noise power increases with bandwidth
- Implicitly recognizes optimum receiving bandwidth exists; then

  "select carrier frequency at which [noise} spectrum is low"

> *Early version of WWII "matched filter"*<

Noise performance understanding,late 1920s

- Design systems to max. SNR:

  radio, “static”; telephony,fluctuation noise
- Radio, use directional antennas, move to higher frequencies
- Telephony- Concept of noise spectrum accepted
- Design selective circuits to max. SNR-

  matched filter-like approach

Early 1930s- Armstrong, Wideband FM

- Edwin H. Armstrong, Columbia University: interested for years in reducing static
- By 1927, idea to cancel noise at adjacent frequencies- published 1928
- Carson replies- noise cannot be cancelled:

“ Static, like the poor, will always be with us.”

Armstrong, Wideband FM (cont)

- Armstrong continues work-
  about Sept. 1931- Eureka moment!:
  Use wide-deviation, wideband FM to reduce noise
  (Armstrong working with RCA on FM)
- Applies for patent, Jan. 24, 1933
- Patent No.1,941,069; *Radiosignaling,* issued Dec. 26 1933

Armstrong, Wideband FM (cont)

"I have discovered that by imparting greater swing to the frequency of the transmitted wave than exists in the disturbances due to tube [noise] and providing means for selecting these large swings of frequency which are…not responsive to the lesser swings due to tube [noise]…that a very great improvement in transmission can be produced."

Armstrong, Wideband FM (cont)

Comments:

1. He focuses on tube noise reduction- operates at short wave range, much- reduced static
2. Well-aware of, and spells out, tube noise properties, as described by Carson et al (Tube noise here = shot +thermal noise)
3. Work here a spectacular leap ahead:

   First example, “bandwidth-noise tradeoff”

Armstrong, Wideband FM (cont)

- Armstrong gave demos, system well-received
- 1936 paper used vector approach to show wide-deviation/wideband noise improvement.
- Many other papers followed (Ex: Carson!)
- Led to intensive study of noise in communication systems

Years Following

- 1930s:

  Studies begin, noise through non-linear systems

  Statistical characterization: *Gaussian!*

  Alex Reeve, 1937, PCM

  Noise figure concept
- WWII: Radar, focus on signals in noise