

# 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/Information Theories
- 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:

- “Warmeffect”- 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