Critical Steps to AM Revitalization

Presented by
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Why AM Radio as a Media Resource is Irreplaceable

- During Hurricanes Katrina and Sandy AM Radio Stations With Available Diesel Generator Power Proved to Be the Most Reliable Source of Information
- During the Earthquake in Northern VA that shook downtown Washington, DC AM Radio Stations were again a primary source of news and information when cell sites were totally saturated with users
- AM Radio Stations Cover a Larger Demographic Area Than FM or TV Stations, Particularly at Night Due to Over the Horizon Skywave Coverage

AM Radio is in Dire Straits

- **Listenership fading steadily (<17%)**
  - High levels of reception noise (RFI/EMI)
  - Absolute dominance of FM radio
  - Internet radio, MP3 players, personal devices
- **Total revenue is $2.2 B but falling**
  - Mostly from large markets, chains (2012 figures)
  - Many small-market stations near failure
- **What's the real problem?**
  - Poor reception conditions, poor AM radio receivers
  - Terrible audio quality (2.5-kHz typical bandwidth, no bass)
  - With the low audio quality, it's hard to program music
  - AM cannot survive with news/talk alone!

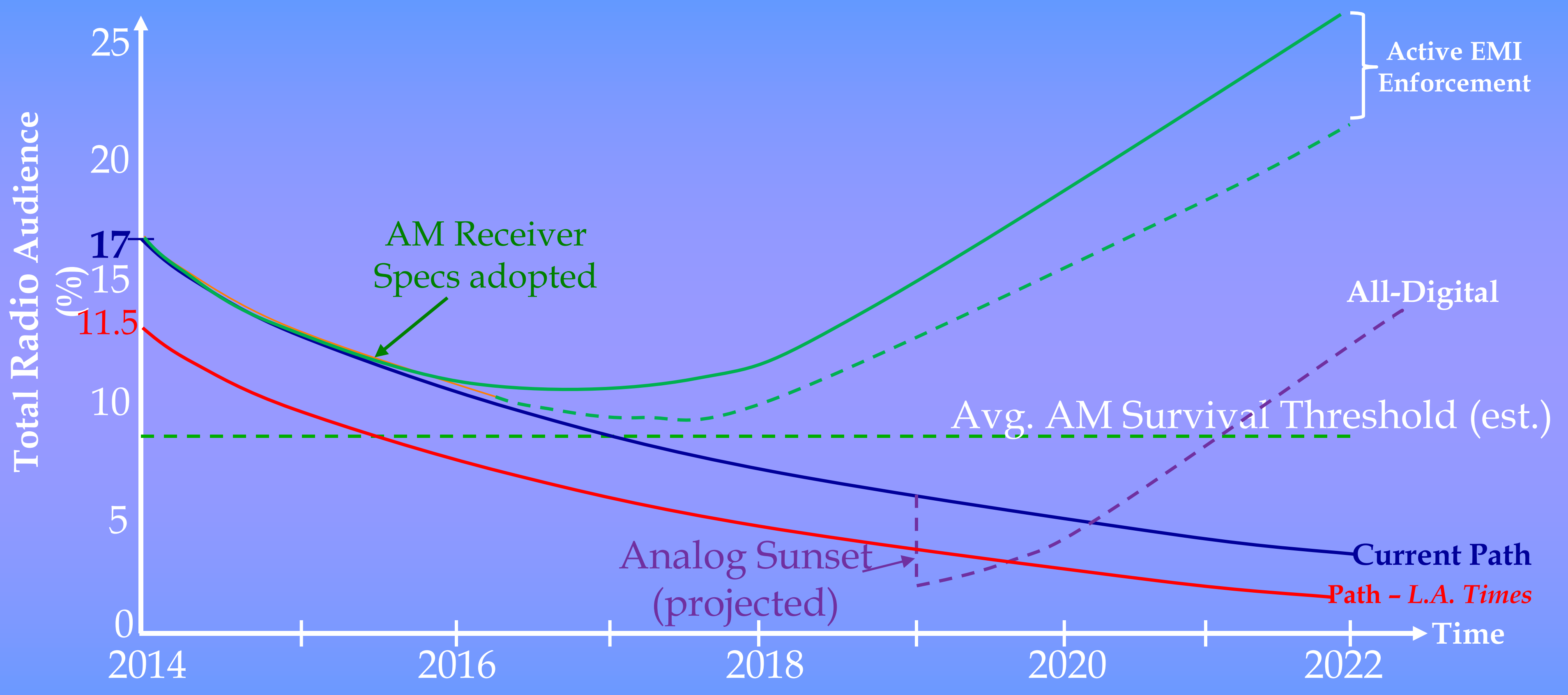
Three Paths Forward for AM

- (1) **Continue current course**:
  - No significant actions; some minor (helpful) Rules changes
- (2) **Order analog "sunset":**
  - With sufficient HD radio penetration (2019?)
  - Abrupt, large loss of audience; economic shock
- (3) **Three Critical Steps to AM Revitalization**
  - Conduct a noise study in the 0.5MHz-2GHz band and review and modify as appropriate the Part-15 and Part-18 EMI regulations
  - Establish AM receiver specs to provide parity with FM
  - Promptly adopt AM synchronization rules

Legal Precedents for Strong Action

- **The Commission has proactively managed the broadcast services in the past:**
  - **Denial of AM stereo in 1961 to assure success for FM**
  - **Adoption of FM stereo standard (1961)**
  - **UHF-TV floundering; All-Channel Receiver Act passed (1961)**
  - **Commission solicited AM stereo proposals (~1979-80)**
  - **Magnavox CPM system selected (1980);** lawsuits threatened
  - Commission adopted "marketplace approach" (1982) ⇒ failure for AM!
  - **TV stereo (BTSC) adopted by industry with Commission blessing (1984)**
  - AMAX receiver standards (1993); no Commission mandate ⇒ failure
  - **Final CQUAM approval in 1993**; too late without receiver mandates
- **AM has been left to drift too long; the situation is now desperate!**
- **Industry will not move on its own, so it's up to the Commission to move in *the public interest* to preserve AM**

Projected AM Listenership



- Scenarios versus estimated AM survival share threshold
- Aggressive, prompt action is needed to save AM radio!

Part-15 EMI Enforcement:
"Do or Die" for AM Radio

- **AM is slowly drowning in a sea of noise (QRM)! Analog & Digital**
  - Power lines (high & low-voltage) – poor maintenance
    - Bad insulators, bushings, arcing transformers
    - Ineffective RFI suppression & grounding
    - Proximity to roads
  - Telephone, cable feeders (DSL, CATV signal leakage)
  - Consumer devices with radiation & shielding issues
    - Computers, modems, switching power supplies, etc.
    - Fluorescent & LED lamp ballasts, dimmers
    - LCD & plasma HDTV sets, home A/V gear
- **The legal solution requires active enforcement now!**
  - **Part-15 Rules need to be re-evaluated respective to the present noise environment:**
    - **Unintentional Radiators (§47 CFR 15, Subparts A & B [15.209, 15.221])**
    - **Intentional Radiators (§47 CFR 15, Subparts A & C)**
    - **Home devices (Digital Devices Part B)**

Part-15 EMI Enforcement:
"Do or Die" for AM Radio

- FCC Lab should demand valid Part-15 certification from vendors (e.g., Wal-Mart, Sears, Best Buy, Amazon) & *perform random product testing to assure compliance.*
- Noncompliance should result in hefty fines and (in egregious cases) even marketing injunctions.
- AM stations must become actively involved in reporting Utility & Home Device Part-15 offenses to the Commission.
- Public (non-technical) interference complaints would be directed to the affected stations for follow-up.

INSTRUCTIONS FROM FCC COMMISSIONER MIGNON CLYBURN REGARDING INTERFERENCE COMPLAINTS

- · Submit a filing for the public record at http://apps.fcc.gov/ecfs/
- o Find the most active open proceedings at http://fcc.us/1ILis9g
- o Please note that all submissions are publicly available and searchable on the internet
- · File a complaint about a telecommunications related service at http://www.fcc.gov/complaints
- · File a complaint over the phone or ask general questions about the FCC: (888) 225-5322

Ref: Email from Commissioner Clyburn to Tom King dated 12 Nov 2014 at 5:32PM.

RECENT ARTICLES ATTESTING TO BROADBAND SPECTRAL NOISE AS A MAJOR WIRELESS COMMUNICAITONS PROBLEM

- "Electronic Noise is Drowning Out the Internet of Things" by Mark A. Henry, Dennis Roberson & Robert J. Matheson, posted in IEEE Spectrum 18 Aug 2015
- ITU Report entitled "Drowning in a Sea of Man-Made Noise", IEEE BTS Broadcast Technology Magazine, August 2015

NEED FOR RF NOISE STUDY

- “There hasn’t been a systematic study of radio-frequency noise in the US since the mid-1970’s, when the Institute for Telecommunications Sciences(ITS), a part of the National Telecommunications and Information Administration, last monitored federal use of the radio spectrum.”

* Ref: “Electronic Noise is Drowning Out the Internet of Things”(Note previous slide for details.)

AM Receiver Mandates: *Parity with FM*

- *Low internal noise floor*
- *High overall RF sensitivity, selectivity, and dynamic range*
- *Highly effective noise (EMI) rejection*
- *Full 10-kHz audio bandwidth capability with low detector distortion.*
- *Stereo capability*

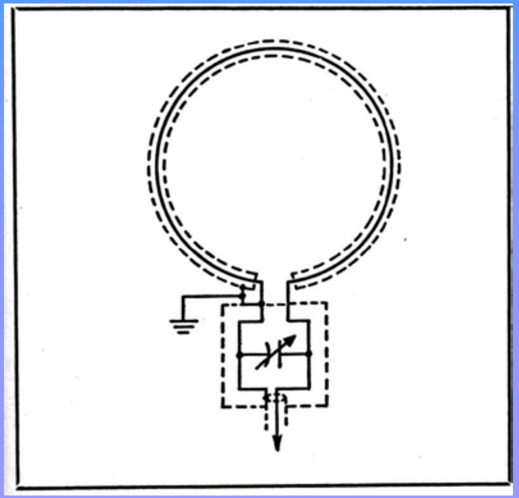
AM Receiver Mandates: *Parity with FM*

- ***Audio Bandwidth:*** 9-10 kHz typical, adaptive with a minimum nominal bandwidth of 7.5 kHz; reduced adaptive bandwidth (~ 3-kHz minimum) permitted in high noise or adjacent-channel interference situations (i.e., nighttime). Variable-Q notch filter @ 10 kHz standard.
- ***Signal-to-Noise Ratio (SNR):*** minimum 55 dB, preferably ≥ 60 dB.
- ***Sensitivity:*** -120 dBm (~1 μV) for 10 dB SNR; <20 μV for 20-dB SNR.
- ***Selectivity:*** 25-50 dB (adaptive, using co-, adjacent-and alternate-channel detection).
- ***Dynamic Range:*** ≥100 dB.
- ***Noise Figure/Rejection:*** ≤ 6 dB; 2-3 dB preferred/≥30 dB impulse noise rejection.
- ***Image Rejection:*** 50 dB or better.
- ***Intermodulation:*** IP_2, IP_3 intercepts +10 to +40 dBm.
- ***IF:*** low with image-rejecting down-conversion, or alternatively, double (up-down) conversion.
- ***Stereo Separation:*** minimum 25 dB, 30 Hz - 10 kHz.
- ***Antenna:*** H-field, or combination H & E field, diversity-type preferred.

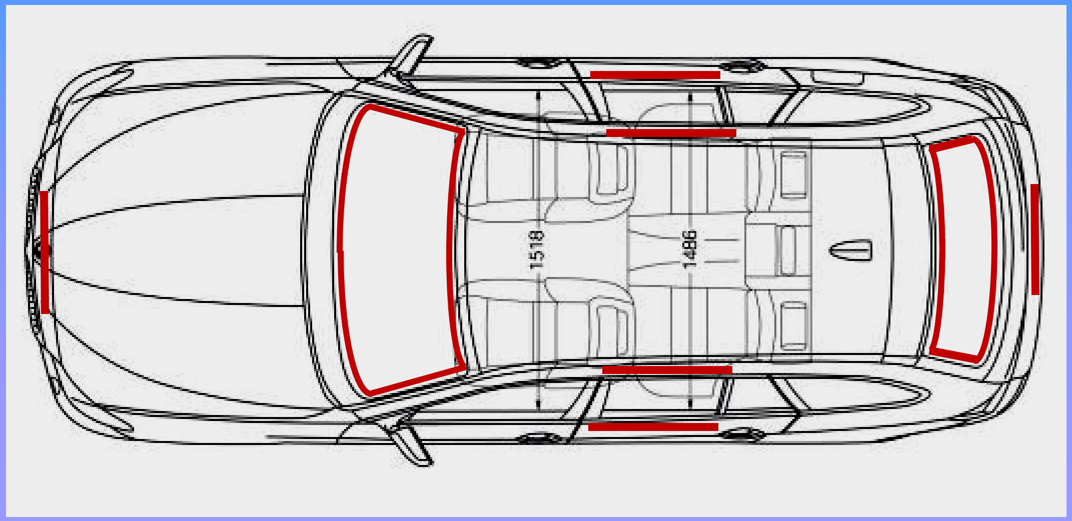
AM Receiver Mandates: *Parity with FM*

Specification	FM (Current)	AM (Current)	Parity?	AM (New)	Parity?
Audio Bandwidth	15 kHz	2.5 kHz	No!	10 kHz	Close
Signal/Noise	65 dB	35 dB	No!	55 dB	Close
Sensitivity (20 db SNR)	2 µV	500 µV	No!	20 µV	Close
Selectivity (Adj./Alt.)	45/60 dB	40/50 dB	Close	40/50 dB (Adaptive)	Yes
Dynamic Range & Intercepts	100 dB	70 dB/ 0-10 dBm	No!	100 dB/ +10-40 dBm	Yes
NF/Noise Rejection	3/50 dB	14/20 dB	No!	2-3/50 dB	Yes
Image Rejection	60 dB	30-40 dB	Close	50 dB/50 dB	Yes
Stereo Separation	35 dB	------	No!	25-30 dB	Yes
Antenna	E-field (Fair)	E-field (Poor)	No!	H-field/ Diversity	Yes

Vehicle H-Field Antenna Implementations



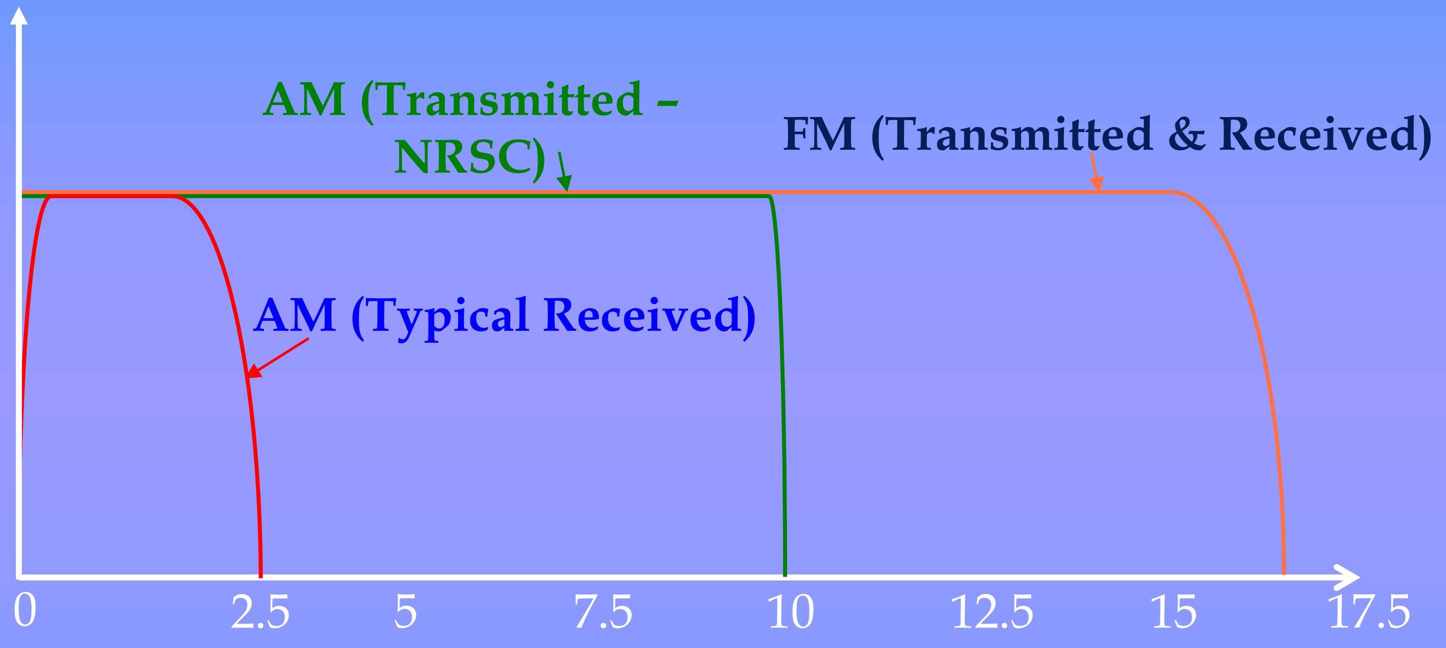
Typical tuned, shielded loop



Potential Loop Locations

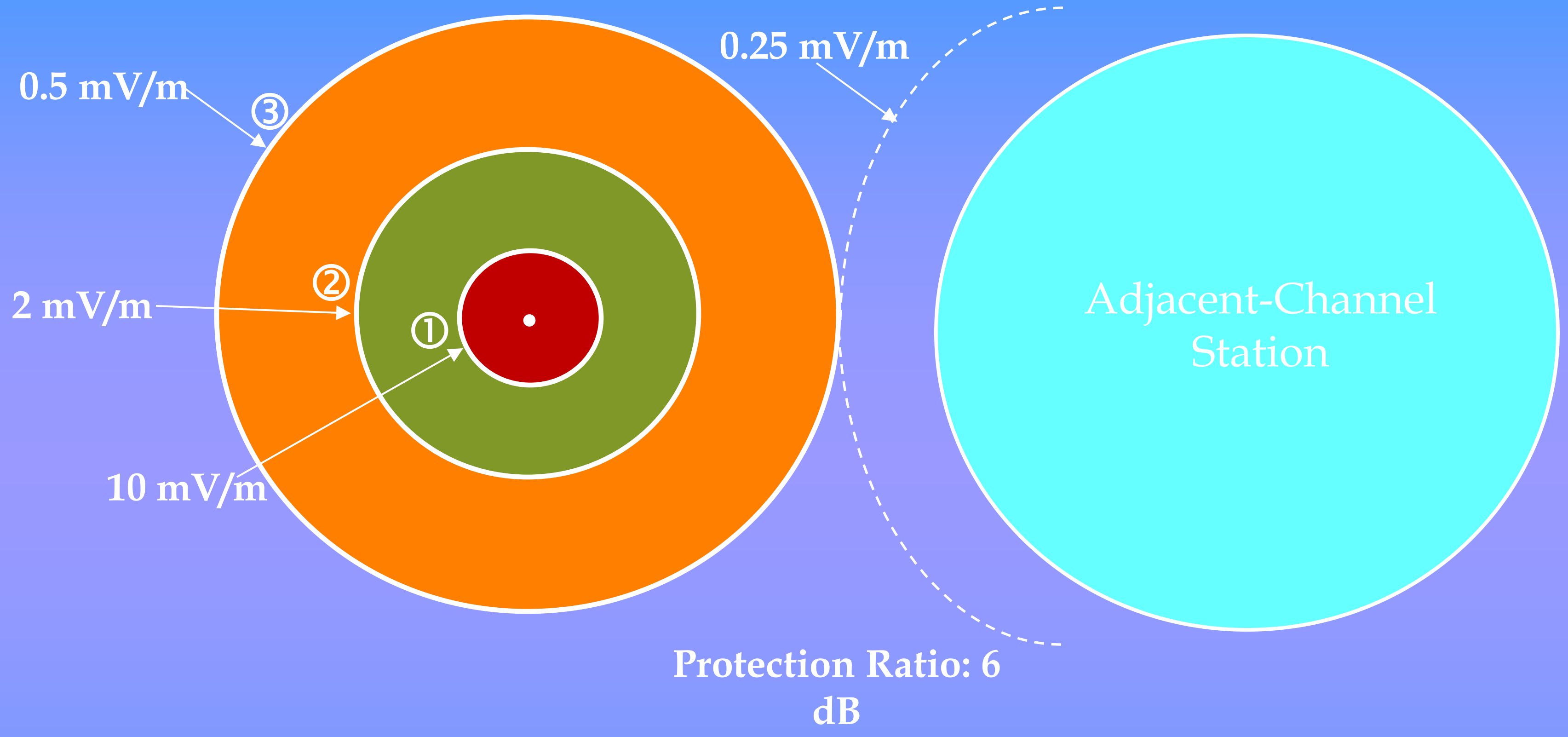
- A shielded loop permits good magnetic (H) field AM signal reception while screening out local E-field noise from auto electronics & power lines.
- **Loop-antenna units (including ferrite loopsticks) can be fabricated at low cost and mounted in windshields, windows, trim, and under plastic body panels.**
- Multiple air-core units, mounted vertically, can be effectively utilized with standard diversity-combining techniques.
- **These AM loops can be configured for good FM reception as well.**

FM vs. AM Audio Frequency Response



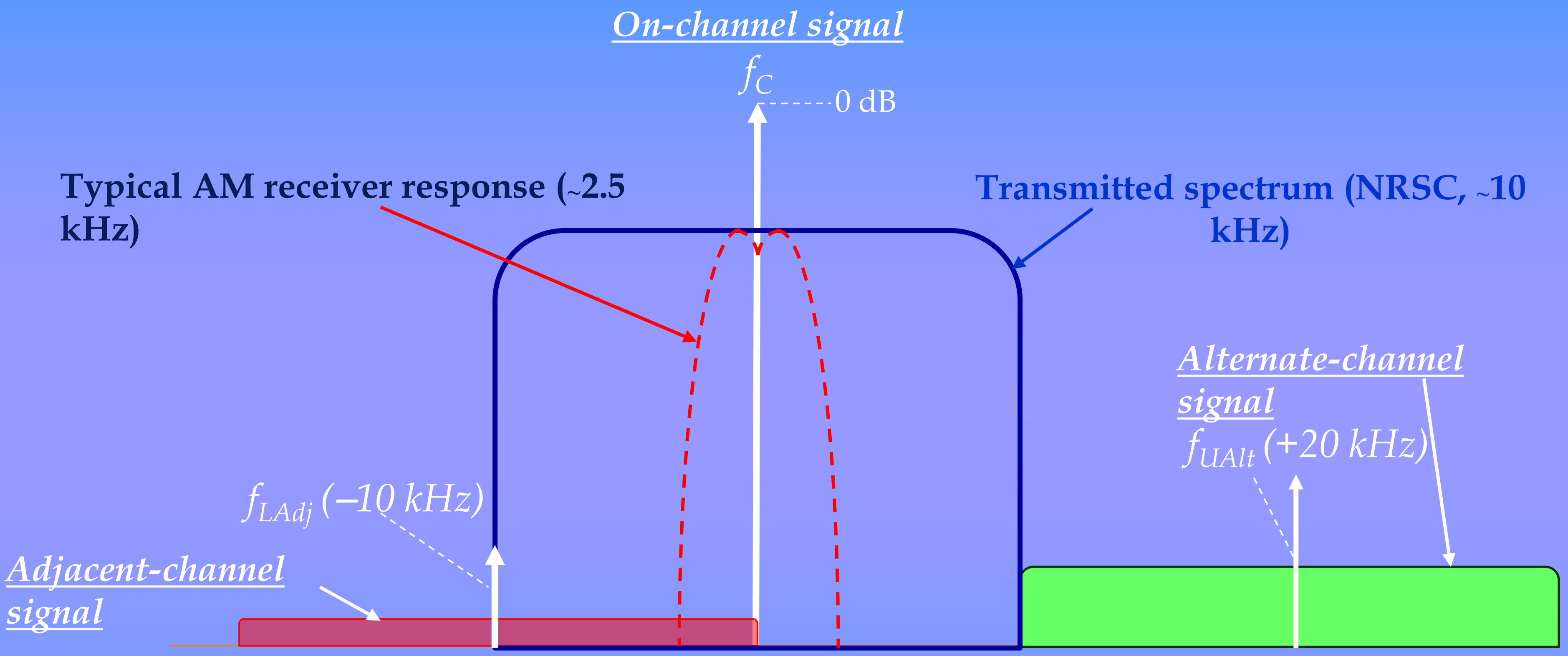
- FM transmitted & received bandwidth ~ 15 kHz ("full-fidelity")
- AM transmitted bandwidth (NRSC) ~ 10 kHz ("fine")
- Typical AM receiver ~ 2.5 kHz + bass rolloff + noise ("telephone-grade")
- With these conditions, how can AM compete or even survive?

AM Reception Cases



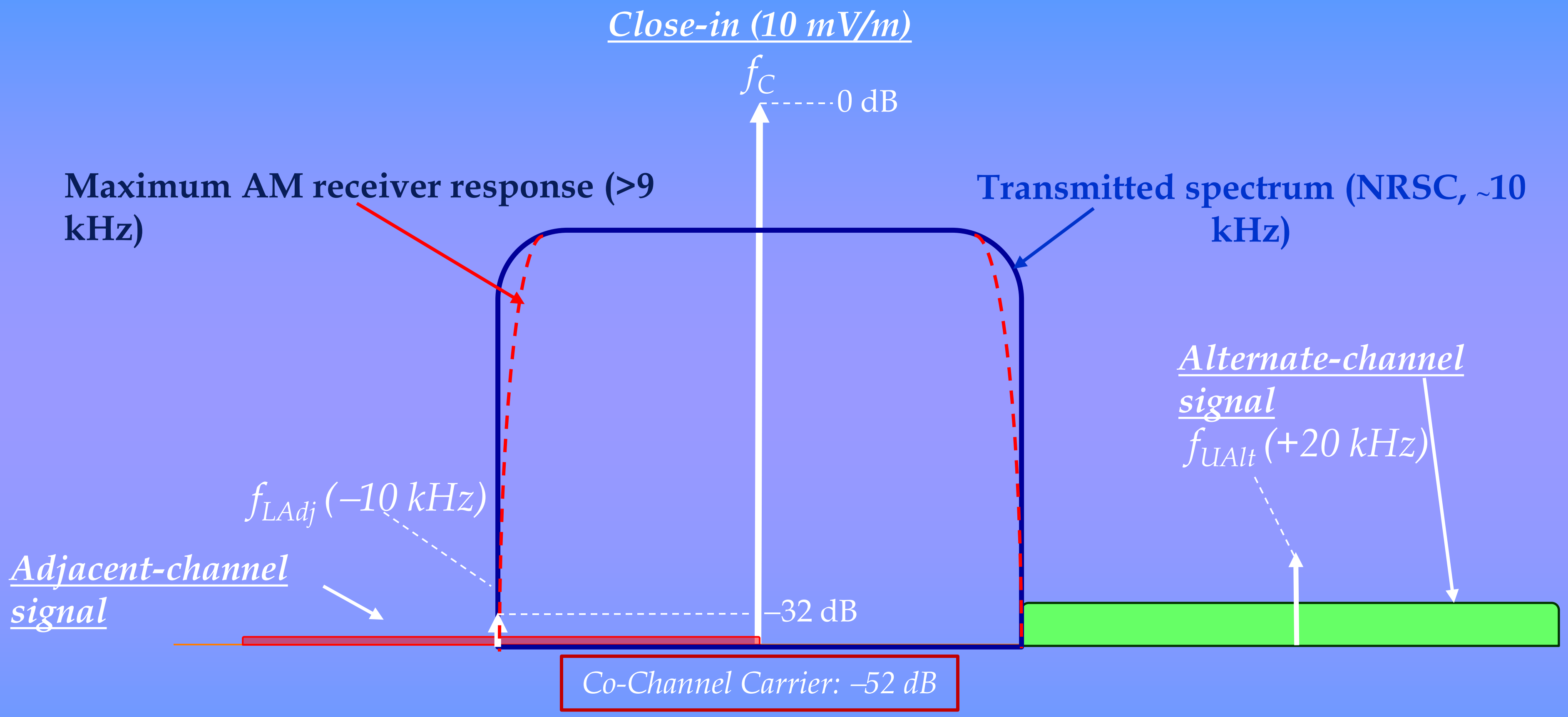
- **<u>Contours</u>: (1) Close-in** [10 mV/m]; **(2) Suburban** [2 mV/m]; **(3) Fringe** [0.5 mV/m].
- **Receiver response dependent on relative carrier & modulation levels.**
- **Dynamic bandwidth, signal cancellation, and audio expansion performed digitally for higher performance plus lower cost & complexity.**
- **Overall cost/complexity comparable to HD radio implementations.**

AM Receiver Frequency Response



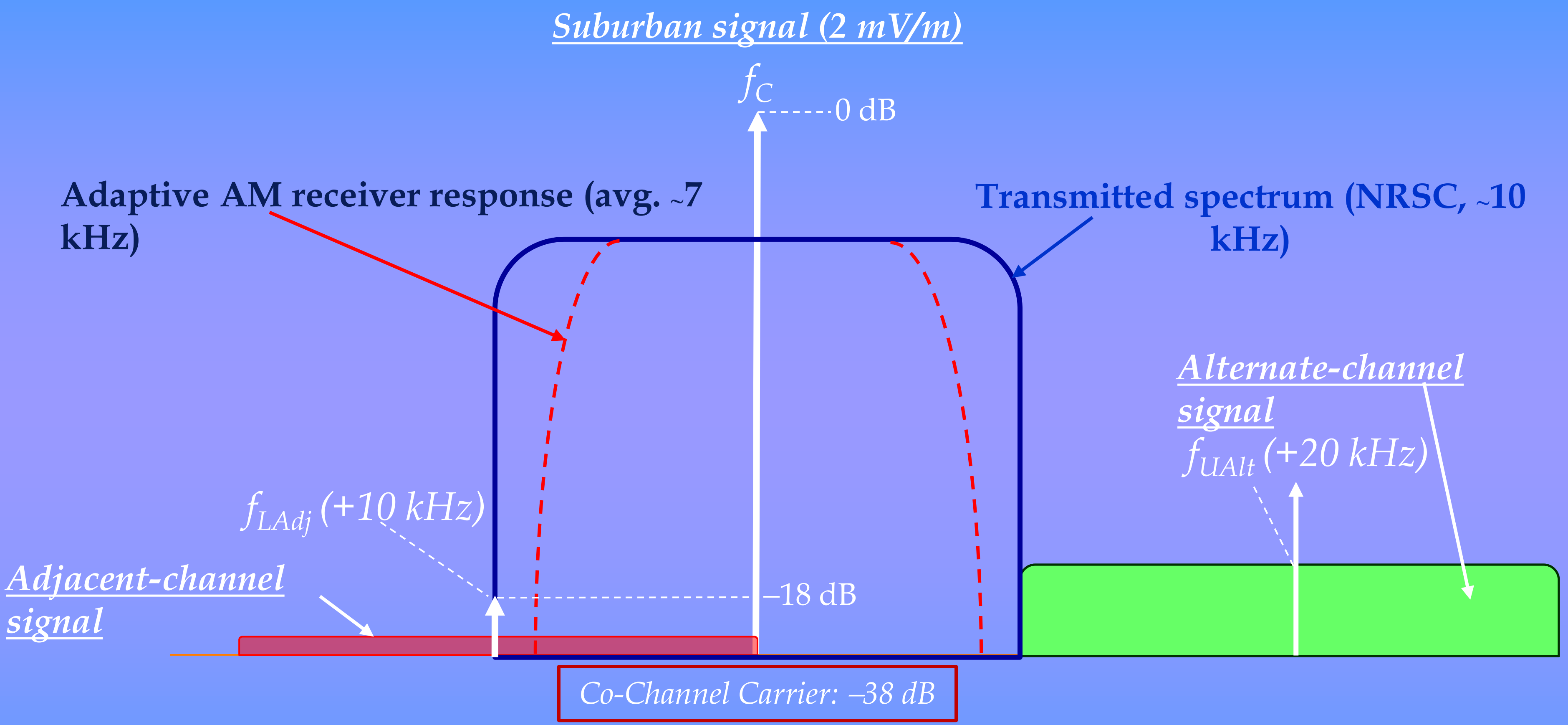
- Current AM receivers reproduce only ¼ of the transmitted bandwidth!
- To "balance" the sound, the bass is cut to compensate for the lack of highs
- Current receivers have no stereo, no noise limiting, poor RF performance

AM Receiver Frequency Response



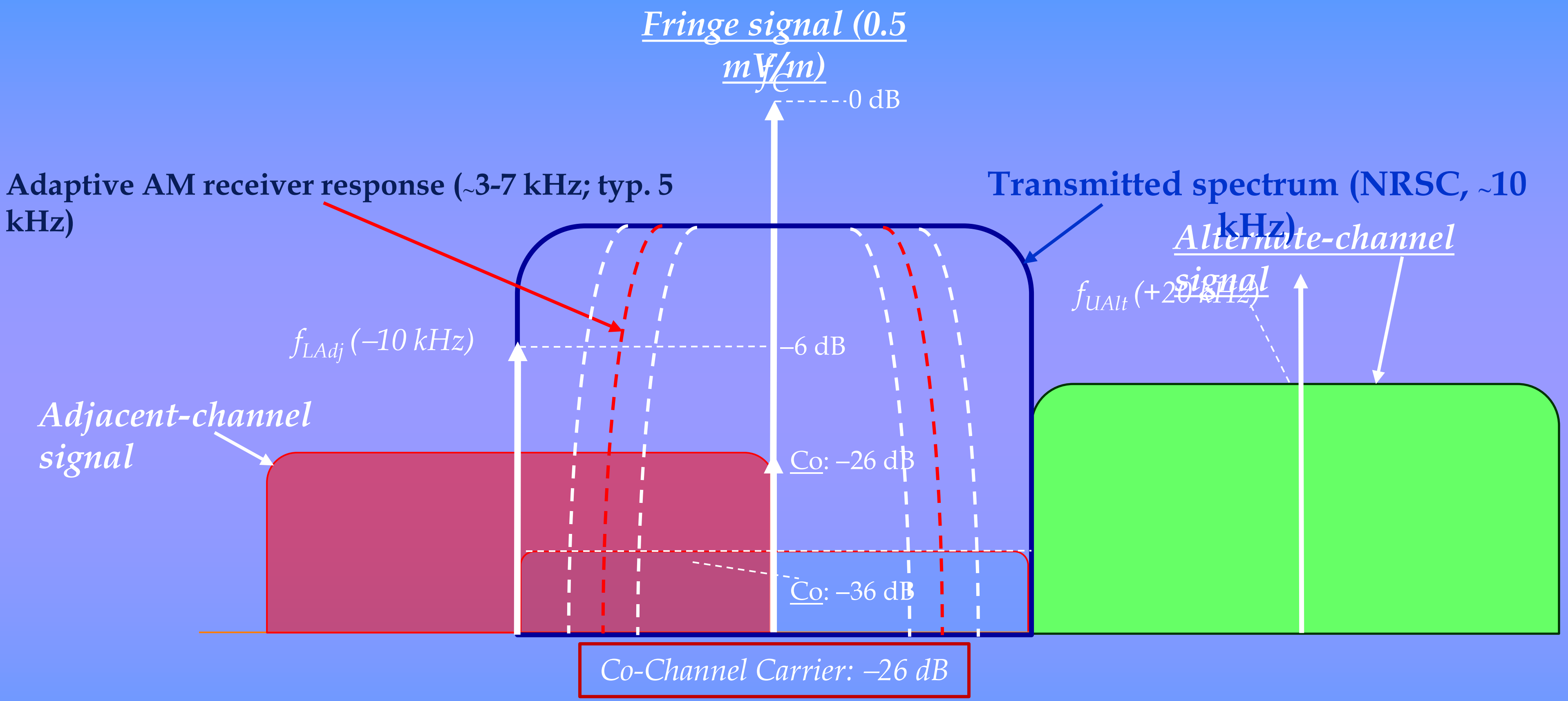
- New AM receivers can reproduce all of the transmitted bandwidth!
- Flat bass response, extended highs, and full stereo separation (CQUAM)
- Multi-stage noise limiting, low internal receiver noise, H-field antennas

AM Receiver Frequency Response



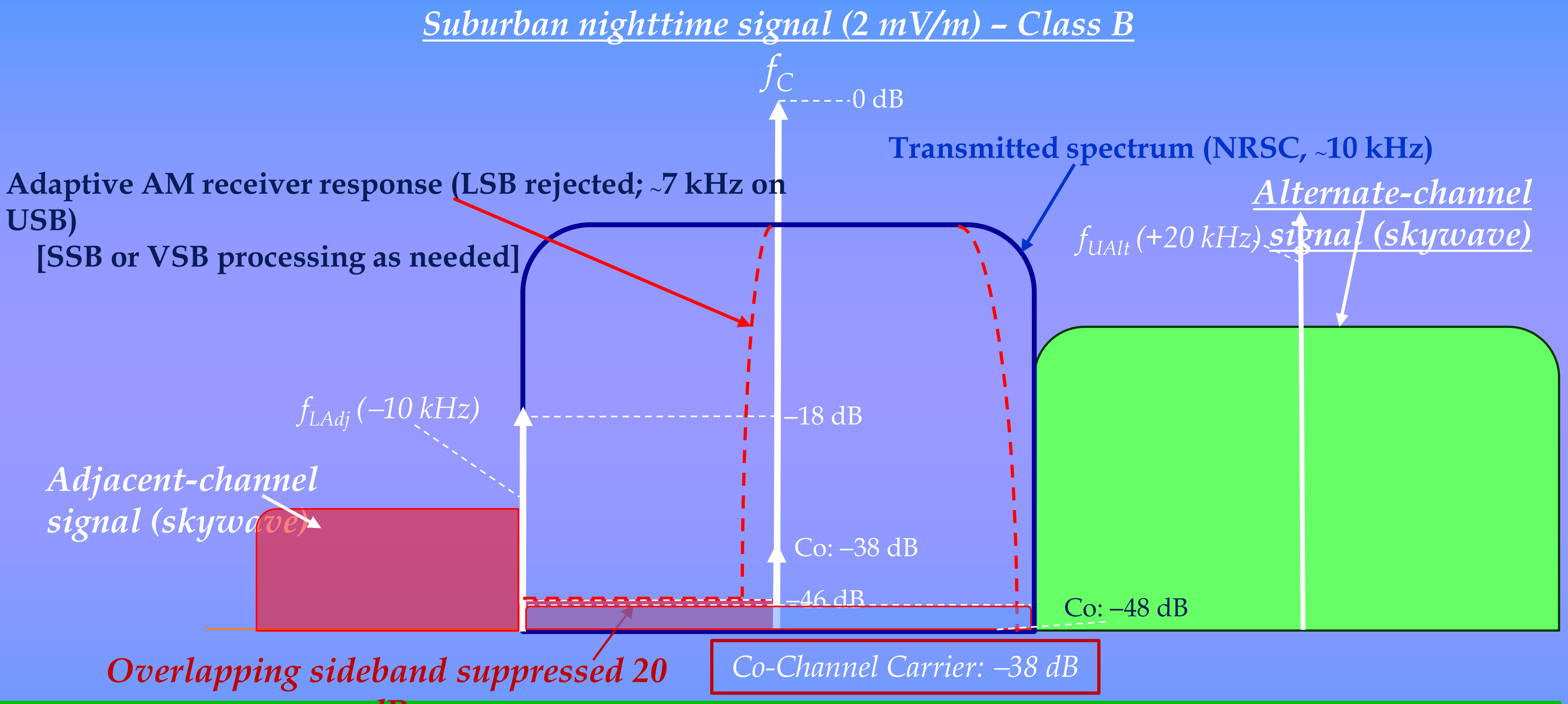
- Adaptive AM receivers can reproduce most of the transmitted bandwidth!
- Bandwidth dynamically controlled by noise, adjacent- & alternate-channel levels
- Advanced DSP algorithms for optimized reception, adaptive noise reduction

AM Receiver Frequency Response



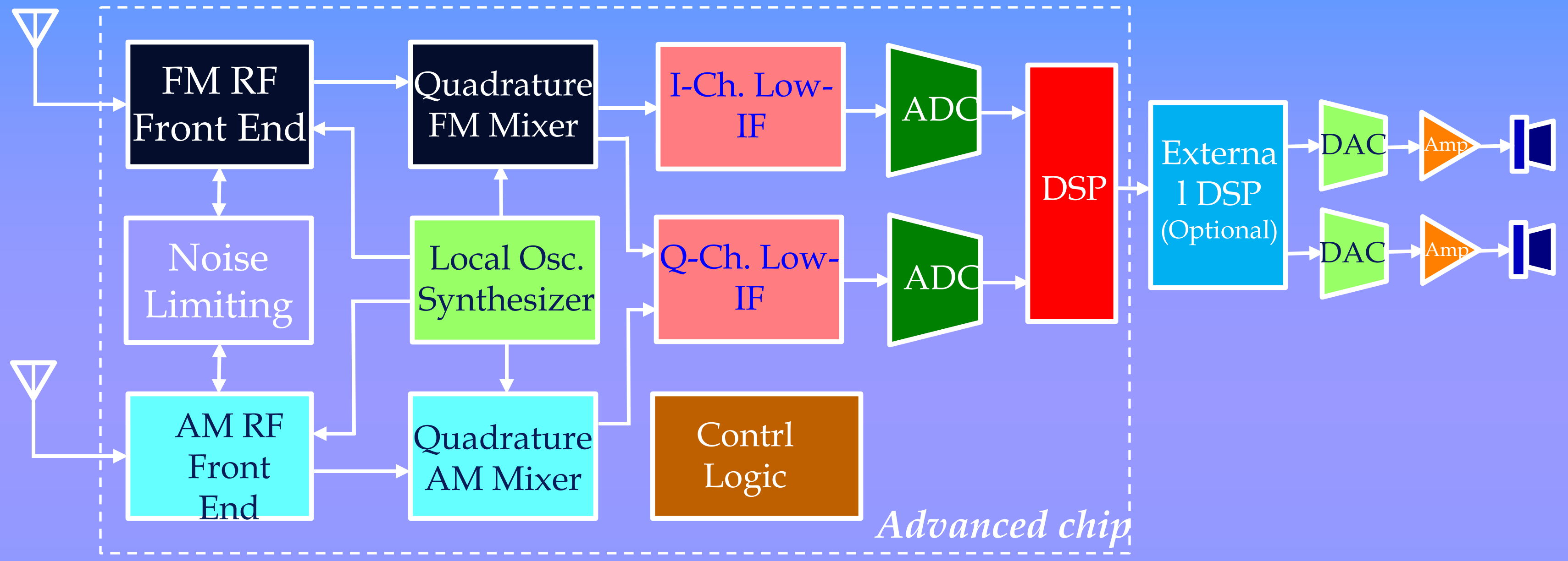
- Adaptive AM receivers can still reproduce most of the transmitted bandwidth!
- Bandwidth dynamically controlled by noise, adjacent- & alternate-channel levels
- Aggressive DSP algorithms for optimized reception, adaptive noise reduction

AM Receiver Frequency Response



- Adaptive AM receivers can still reproduce most of the transmitted bandwidth!
- Bandwidth dynamically controlled by noise, adjacent- & alternate-channel levels
- Aggressive DSP algorithms for optimized reception, adaptive noise reduction; e.g., asymmetric filtering, SSB/coherent techniques, interference cancellation

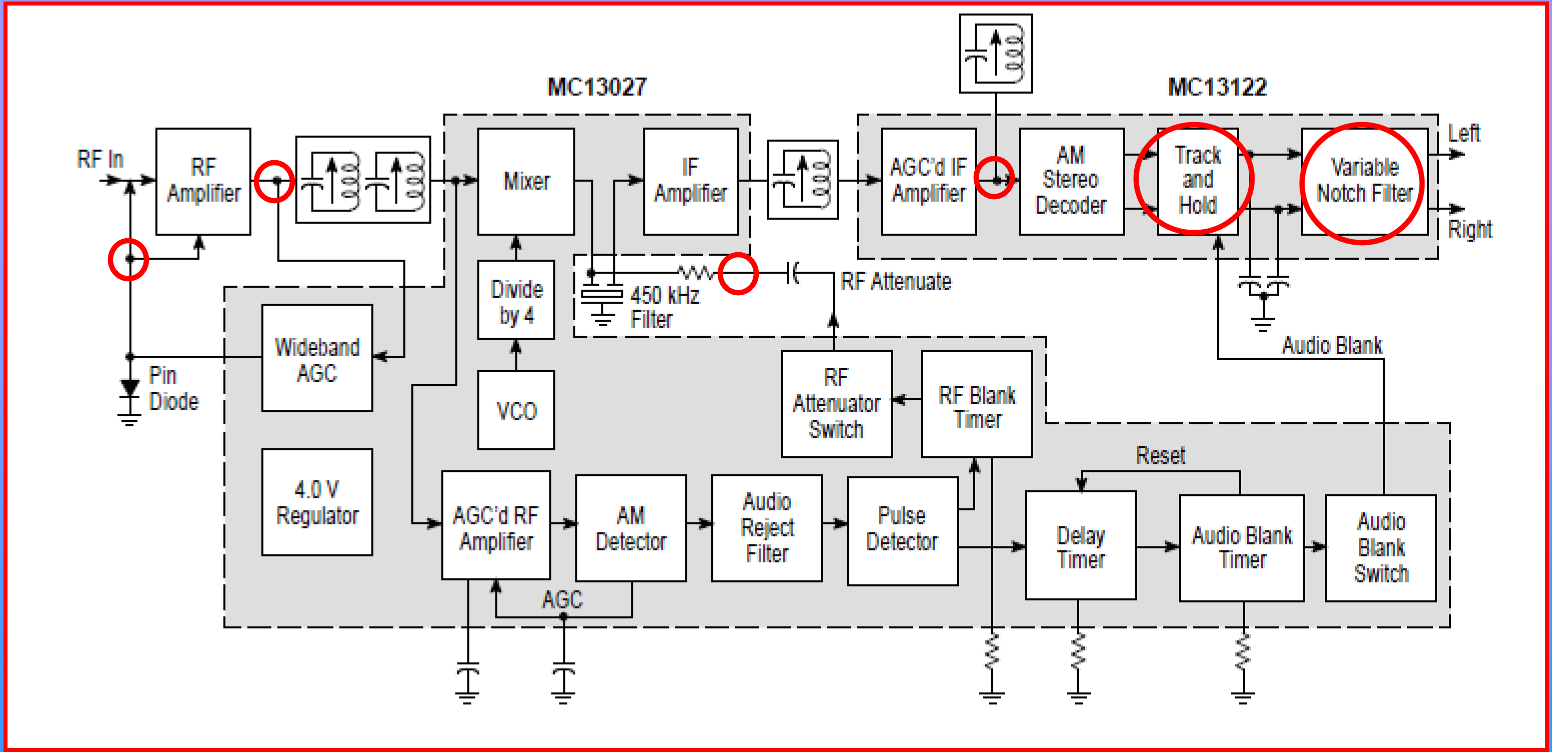
Typical Advanced Receiver Architecture



- High-gain, noise-limiting, low-noise Front-End stages (AM & FM)
- Low-IF or Dual-Conversion adaptive-bandwidth architecture
- DSP-based RF/detection adaptive signal processing
- Optional DSP RF/audio signal optimization device

Receiver Noise Rejection

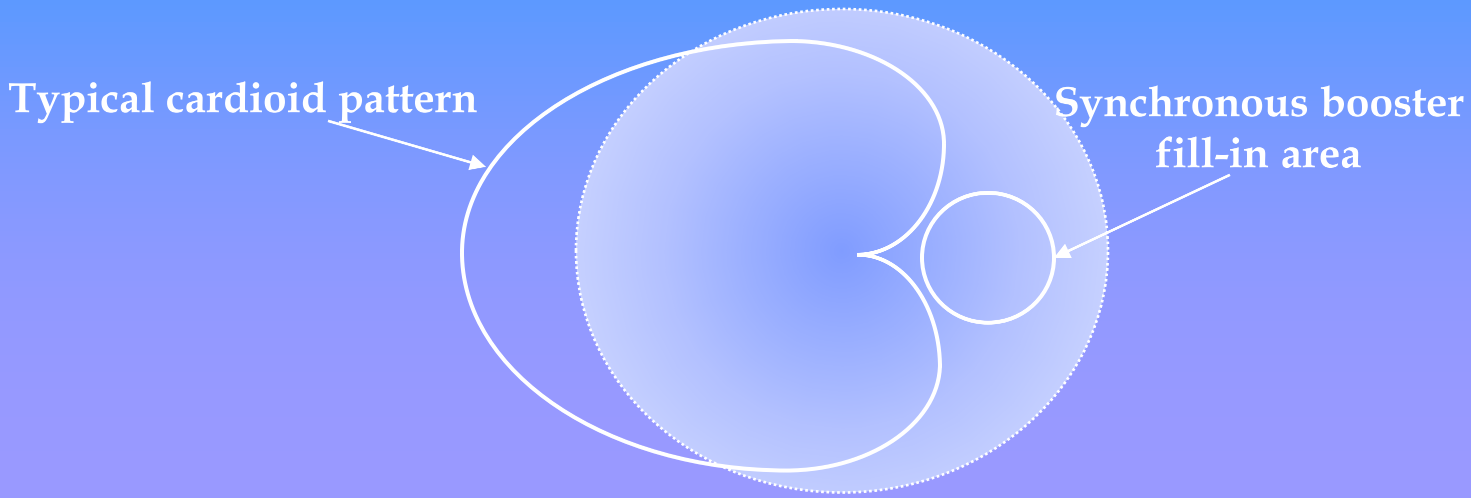
- **Multi-stage noise limiting (re Motorola CQUAM chips ~1995)**
  - **Antenna input/RF front-end** (fast clamp, PIN diode)
  - **Mixer output** (triggered blanker)
  - **IF output/Detector input** (delayed blanker)
  - **Audio output** (delayed sample-&-hold)
  - **Variable 10-kHz notch filter**



DSP Techniques for Receiver Noise Rejection in Kintronic Labs Receiver Under Development

- Signal delay with look-ahead processing
- Memory storage for signal averaging
- Adaptive limiting & blanking (with delays)
- SSB/VSB processing for adjacent-channel interference (ACI)
- Asymmetric sideband filtering for ACI rejection
- Dynamic front-end AGC & Antenna tuning
- Fast, dynamic spectral measurements (L_{Alt}, L_{Adj}, On, U_{Adj}, U_{Alt})
- Dynamic audio noise reduction/expansion
- Fast noise-floor assessment
- CQUAM stereo separation correction
- Program-dependent bandwidth control (tailored for nighttime)
- Synchronous detection for lower distortion & selective fading

Synchronous AM Boosters for Null Fill



- Low-power, low-cost synchronous boosters can provide useful fill-ins for covering populated areas lying in pattern nulls.
- Boosters can be used daytime and/or nighttime as needed.
- Coverage of outlying suburbs can be greatly improved.
- Allocations can generally be handled under existing rules.

What are the Potential Benefits to AM?

- Elimination of co-channel carrier beats and beat-modulated audio intermodulation effects.
- Because AM radio coverage is intrinsically interference-limited, by reducing the co-channel beats we can enlarge the useful coverage area!
- Since the carrier is statistically stationary and ~10-12 dB (3-4 ×) above the average modulation sideband power, a ***significant*** improvement in listenable coverage area is possible (***and*** fewer tune-outs).
- ***The bottom line***: more coverage = more listeners = more revenue!

Existing §73.182 Co-Channel Rules

Class	Channel	Contour (Day) µV/m	Contour (Night) µV/m	Interfer. (Day) µV/m	Interfer. (Night) µV/m
A	Clear	100	500 (50%SW)	5	25
B	Clear Regional	500	2000 (GW)	25	25
C	Local	500	—	25	—
D	Clear Regional	500	—	25	—

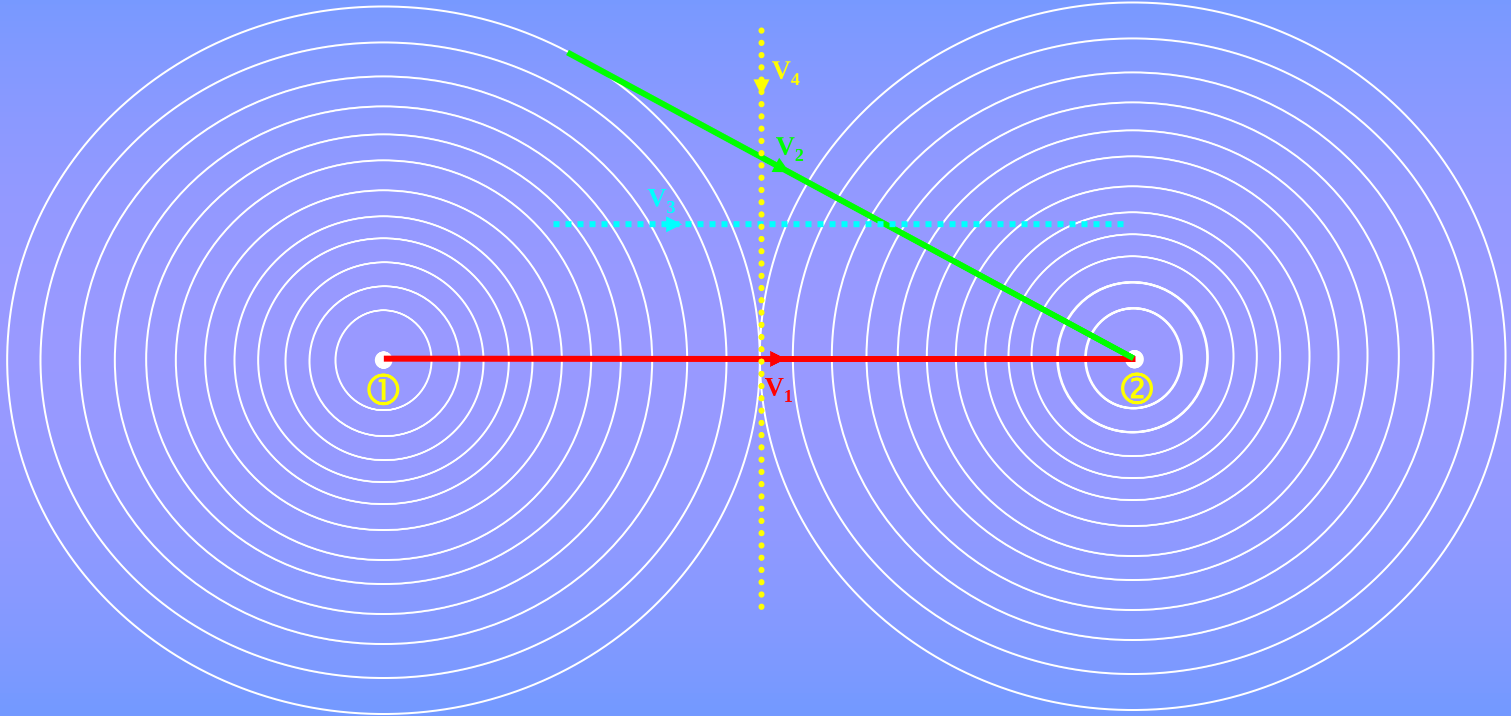
Class A stations are protected to the 0.1 mV/m contour (0.5 night); interferers are ≥ 26 dB down.

Class B, C, & D stations are protected to 0.5 mV/m (2.0 for B at night); interferers ≥ 26 dB down.

Other advantages of synchronization

- With static beats eliminated, Doppler shifts must be considered in station mild-overlap areas for mobile receivers; due to fast AGCs, not really a problem.
- The technology makes the idea of a synchronous, phase-tracking co-channel low-power AM repeaters feasible for "filling in" poor coverage areas.
- In addition, very wide-area single-frequency network broadcasting with satellite audio distribution is also a possibility.
- AM stations could be used as reference frequencies!
- Receiver AGCs will no longer have to deal with beats.

Field Contours of Overlapping Synchronous AM Transmitters with Typical Mobile-Receiver Trajectories



(1) $f_{beat}(total) = \Sigma_n f_{beat}(n)$

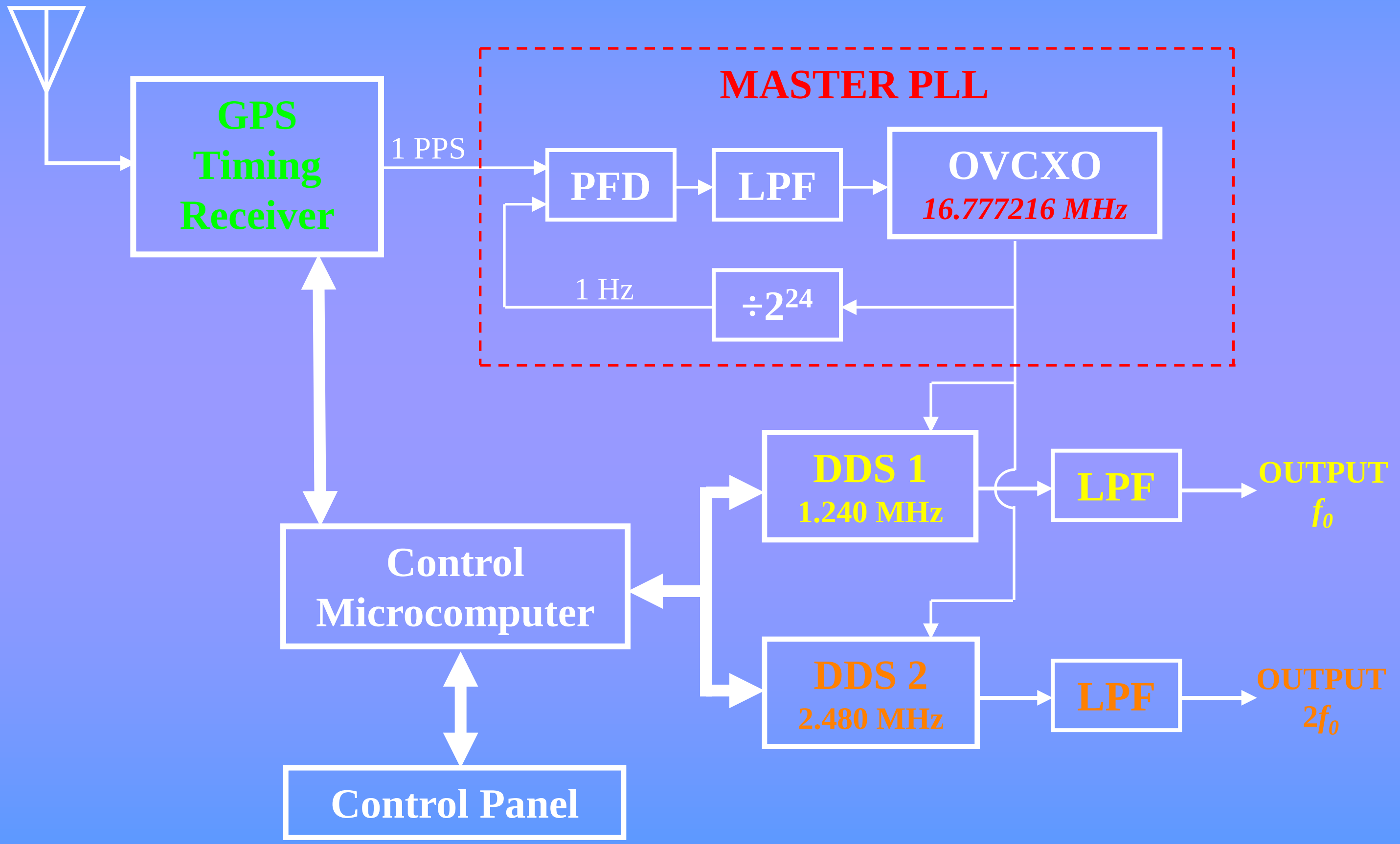
(2) $f_{beat}(n) = (\nu R_n \cos \theta_n)(f_0/c)$

where $f_{beat}(n)$ is the nth beat frequency, νR_n is the velocity relative to station n, θ_n is the angle of the trajectory from the radial from station n, f_0 is the original carrier frequency, n is the number of stations, and c is the speed of light.

Maximum Doppler shifts (on path 1) of about ± 0.1 Hz/MHz at receiver velocity of 30 m/s (67 mph).

AM Synchronizer Unit

Typical Block Diagram



Using 2^{24} Hz as the DDS clock assures that true integer frequencies can be generated!

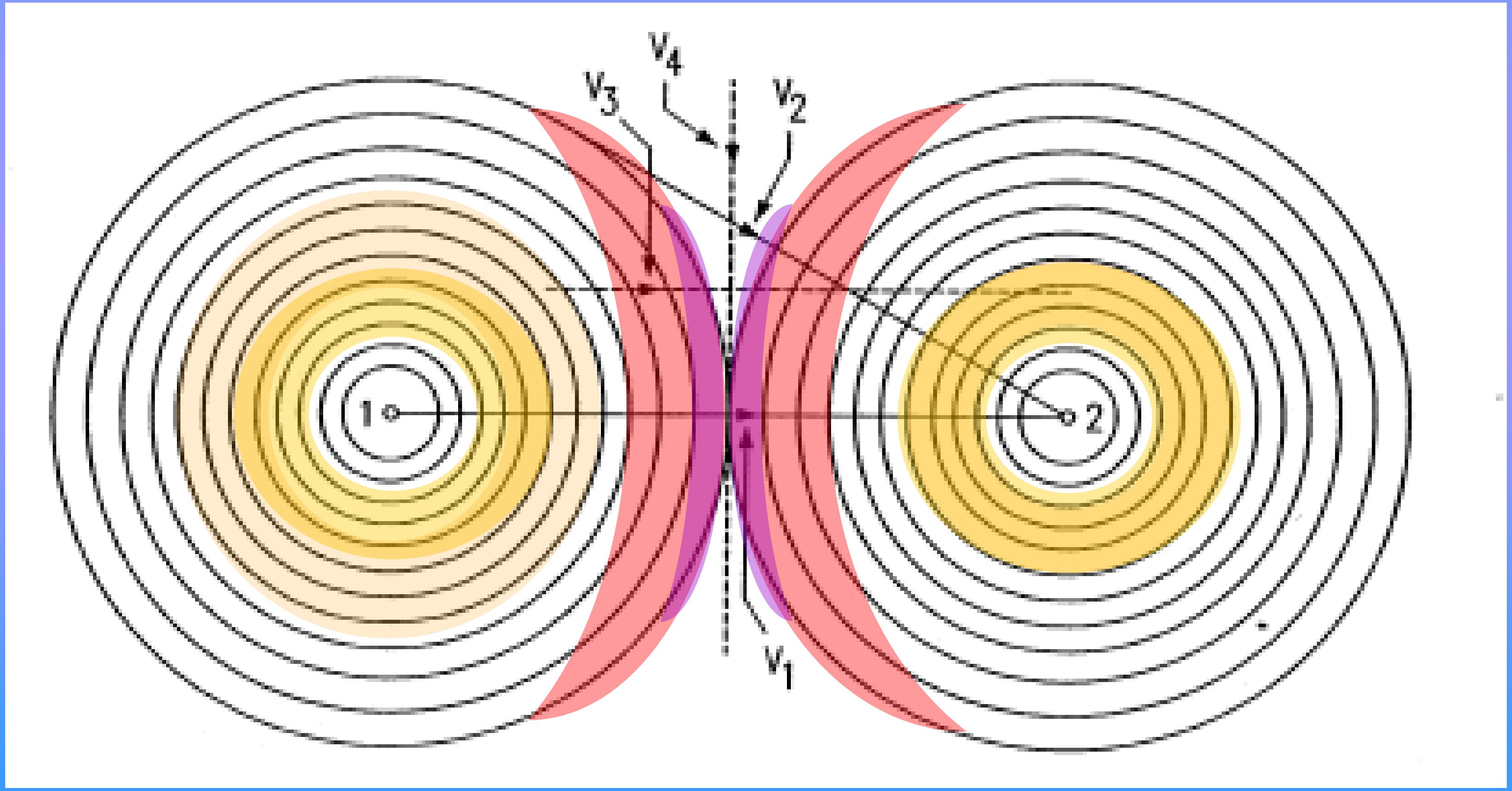
AM field listening observations

- Carrier beats are the dominant effect — the rates vary from sub-Hertz to about 30 Hz!
- In the worst cases, beat frequencies of ~ 20 Hz cause “Donald-Duck” effects and severe distortion on background audio modulations.
- Beats are much lower in expanded band (1610-1700 kHz) — far fewer stations, newer transmitters!
- Clutter is horrible on local channels; poor coverage!
- Estimated overall typical improvement: 6-10 dB for most stations (talk-oriented).

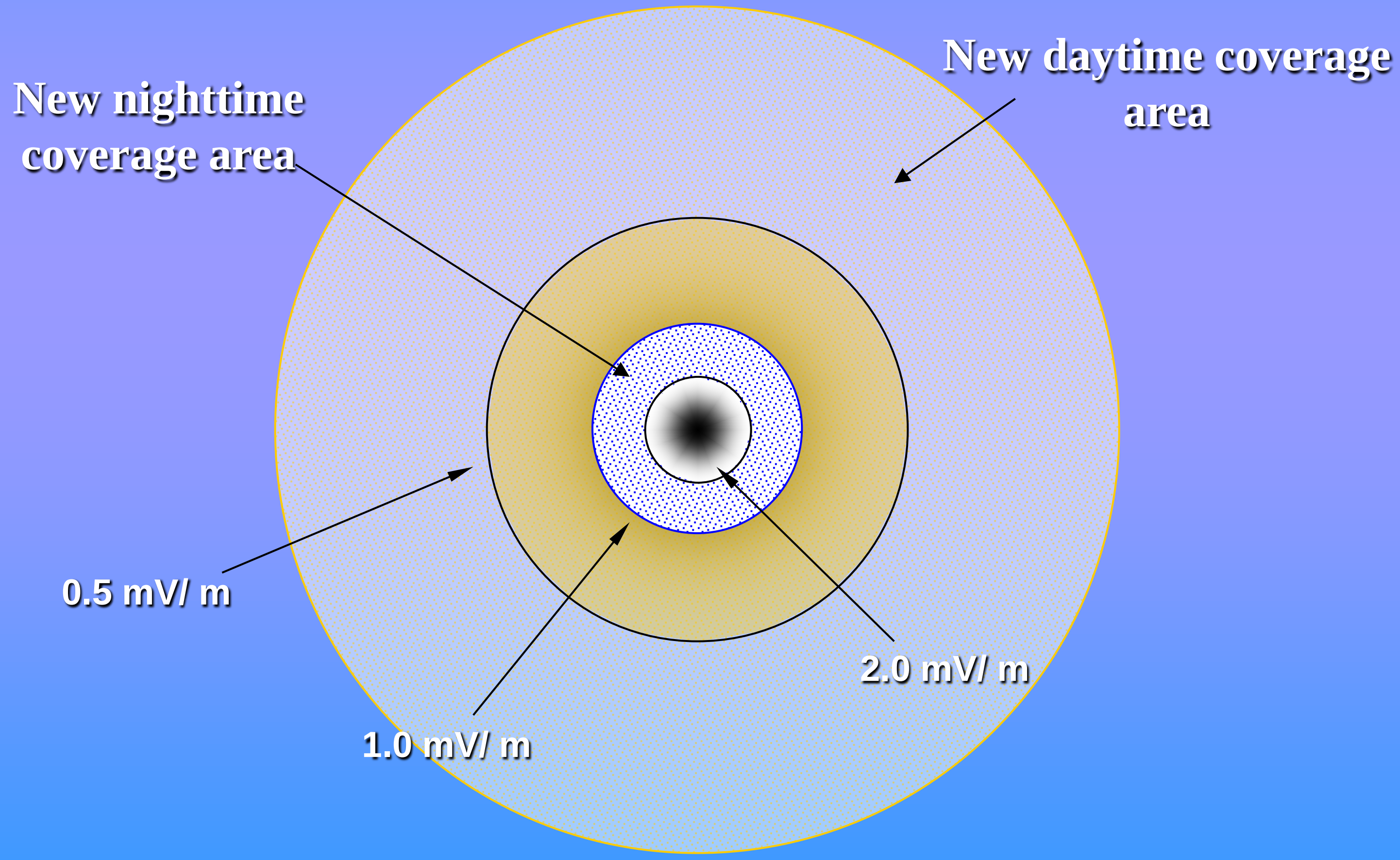
CD of Lab tests is available – contact us!

Plot Illustrating Doppler Effects in Mobile Receivers for Synchronous Stations 1 & 2

Original area Enlarged area Interference area (2:1) Int'f. area (Sync'd)



Effective Synchronous Day/Night Interference-Limited Coverage Improvements (Class B)



Pros and Cons

- Typical enlargement of effective coverage area: ~ 6-10 dB (factor of 2 to 3 in radius = 4 to 9 in equivalent listening area).
- Elimination of all static beats, which are the most objectionable effect and the source of most tune-outs. Doppler $\leq$ 0.2 Hz/MHz at 30 m/s (67 mph).
- Gains greatest for fast music, speech programming.
- Reduction in co-channel beats also benefits HD reception; reduced platform motion for CQUAM AM stereo.
- Masking usually better on wider-band receivers.
- Huge bang for the investment buck for broadcasters!
- Minor or no TX equipment modifications; low cost.
- *Concern: all stations need to synchronize or little benefit!*

What can be done to fix AM radio?

- Broadcasters, NAB, SBE:
  - Adopt synchronous frequency control.
  - Install CQUAM stereo exciters with GPS-based frequency sync
  - Report known sources of noise to the FCC website
  - Work with local congressman and senators to encourage the establishment of new receiver standards
- The Commission:
  - Mandate synchronization (no economic hardship!)
  - Establish a noise study group under the Future of Unlicensed Services Committee of the Technical Advisory Council

What can be done to fix AM radio?

- **Receiver Manufacturers:**
  - Employ ± 10-kHz (adaptive) receiver RF/IF bandwidths.
  - Include CQUAM stereo decoders.
  - Provide 10-kHz notch and selectable/ adaptive IF bandpass filters (±3-10 kHz).
  - Employ broadband noise/impulse limiters.
  - Utilize synchronous detection circuitry.
  - Include very tight RF/IF AGC systems.
  - DSP-based processing for best cost, flexibility *(e.g., Silicon Labs, NXP, TI, ADI, etc.)*
- **Public:**
  - Be pro-active in support of high-quality, free AM radio!
  - Demand better AM receivers!

SUMMARY

The Outlook for AM Broadcasting

(at least, the way we see it!)

- AM, the most spectrally efficient medium, has been essentially technologically orphaned by receiver makers!
- Beats and co-channel intermodulation — the source of most tune-outs — can be significantly reduced at low cost using carrier-synchronization technology.
- The 10-kHz audio bandwidth afforded by NRSC specs, along with CQUAM stereo, can provide very acceptable quality vs. FM for music as well as speech programming.
- The industry has done little to deter the generally miserable bandwidth of modern AM radios and has failed to effectively support AM stereo. *AM receiver mandates are needed!*
- The main needs are for better receiver performance and noise enforcement!