The Engineering Behind 800 MHz Interference

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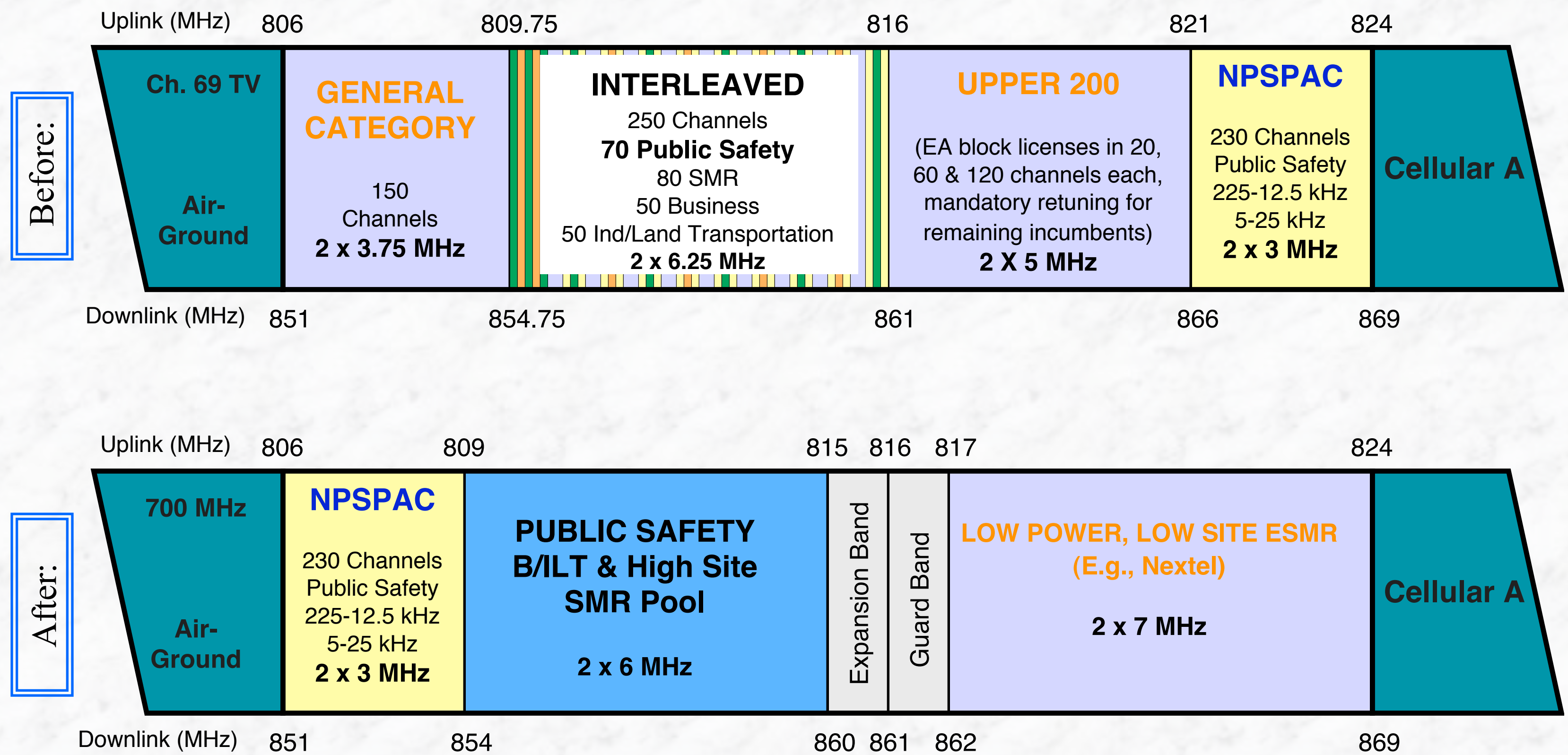
Spectrum Map



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The Near-Far Problem

- Weak public safety signal from distant tower site cannot overcome strong signals from nearby cell site
- Notwithstanding the cell site fully complies with FCC emission rules
- Problem is usually in the public safety receiver, caused indirectly by the cellular operator

Sources of Interference

- **ESMR operator, 862-869 MHz band**
  - Primarily Sprint Nextel
  - Originally iDEN, but iDEN shut down June 30, 2013
  - Being replaced by CDMA and LTE (by mid-2014)
- **Cellular A operator, 869-880, 890-891.5 MHz**
  - Usually AT&T Mobility or Verizon Wireless in urban areas
  - AT&T primarily employs GSM (200 kHz), UMTS (5 MHz)
  - Verizon primarily employs CDMA, EV-DO (1.25 MHz)
  - Both operators building LTE in 700 MHz band
  - Forward link power control makes problem intermittent
- **Cellular B operator, 880-890, 891.5-894 MHz**
  - To a much lesser extent, practically non-existent

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Types of Interference

- **Out-of-Band Emissions**
  - Generated at Nextel or A-Band operator cell site
  - Falls in the RF and IF passband of receiver
- **Receiver Intermodulation**
  - Non-linear mixing of external carriers in receiver front end
  - Interference is created inside the receiver
  - Can be operator-only mixes or Sprint Nextel/A/B cross products
- **Receiver Overload (Blocking)**
  - Only one frequency required to cause problem
- **OOBE Tends Not to be the Problem**
  - Filtering at base station is effective post-rebanding

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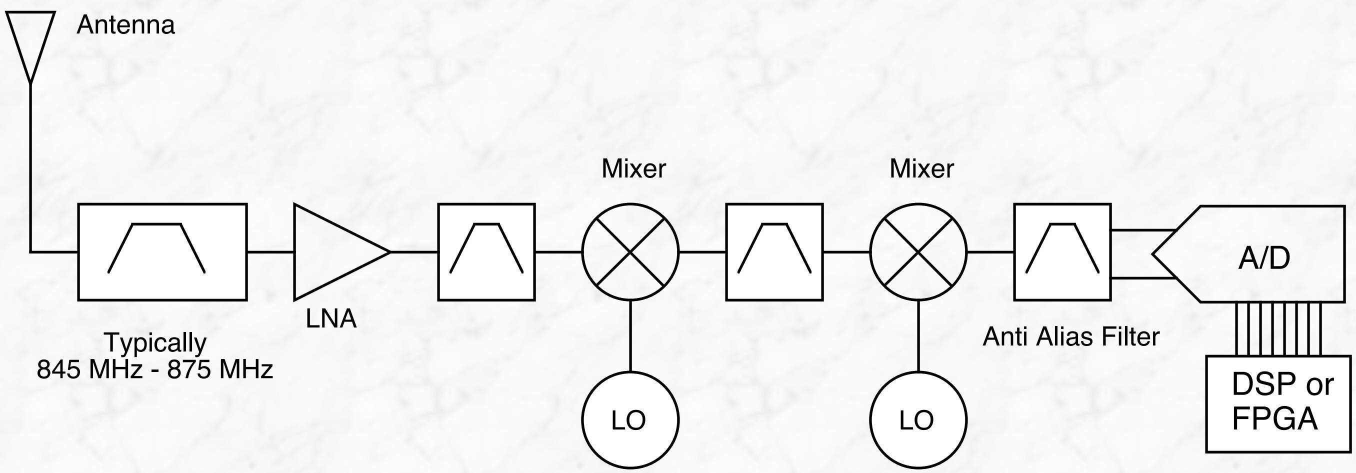
Typical Receiver Front End

- **Bandpass Filter is the Weakness**
  - Typically passes 845-875 MHz
  - Ideally, should be limited to 851-860 MHz
- **LNA is Usually Where IM Occurs**
  - Higher third order intercept is better
  - But higher intercept amp requires more current which is unacceptable in battery-operated device



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Receiver IM & Blocking

- **Non-linear mixing of two or more interfering signals inside the receiver front-end (low-noise amplifier and/or mixer)**

- **Products:**

  3rd Order

  IM Frequency = A + B - C, 2A-B

  5th Order

  IM Frequency = A + B + C - D - E, 3A - 2B, etc.

- **3rd Order Products Cause the Most Trouble**

- **Blocking also occurs in receiver, but caused by single interferer**

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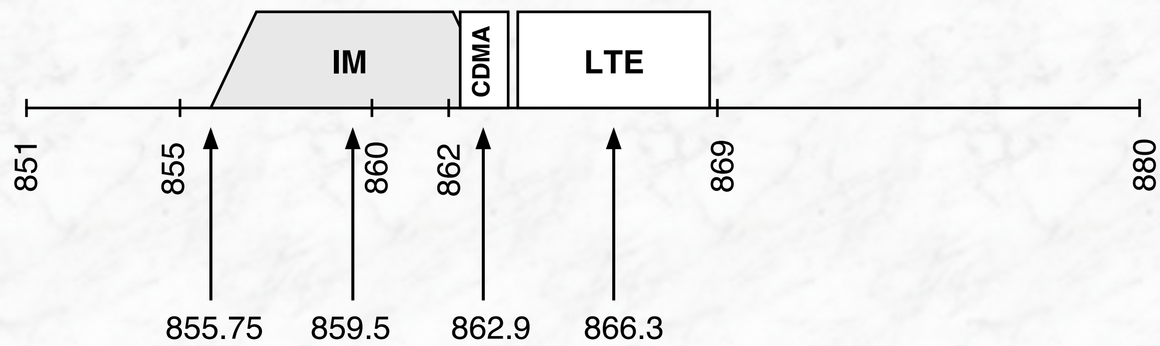
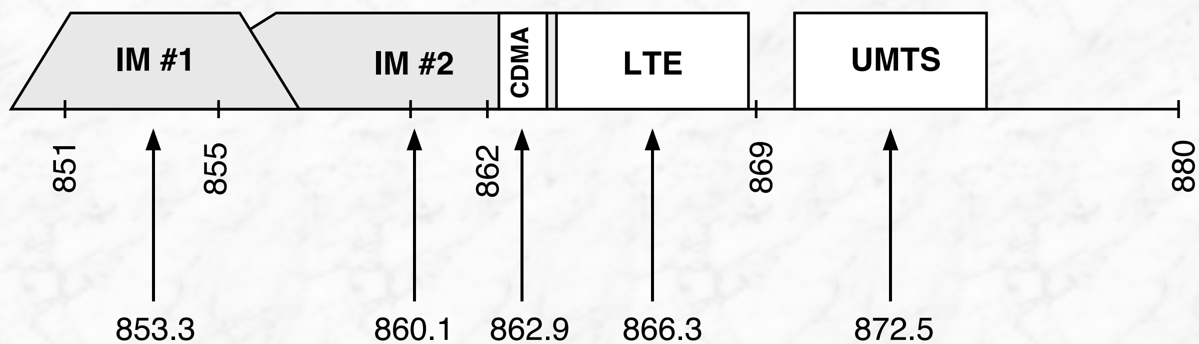
Receiver IM Example

- Sprint-Nextel Alone, 2A-B Product CDMA & LTE



- Sprint-Nextel & A-Band UMTS (Two of Three Products Shown)



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*Third product is A+B-C type, roughly 12.25 MHz wide and centered on 856.7 MHz.

Protection Criteria (FCC 90.672*)

- **Minimum Median Signal Level at Location**
  - Mobile -104 dBm
  - Portable -101 dBm

- **Minimum Sensitivity**
  - Mobile or Portable, -116 dBm

- **Minimum Adjacent Channel Rejection**
  - Assumed to be analog, measured per TIA-603-D
  - Mobile 75 dB
  - Portable 70 dB

- **Minimum IM Rejection**
  - Assumed to be analog, two-tone, measured per TIA-603-D
  - Mobile 75 dB
  - Portable 70 dB

*Also Part 22.970

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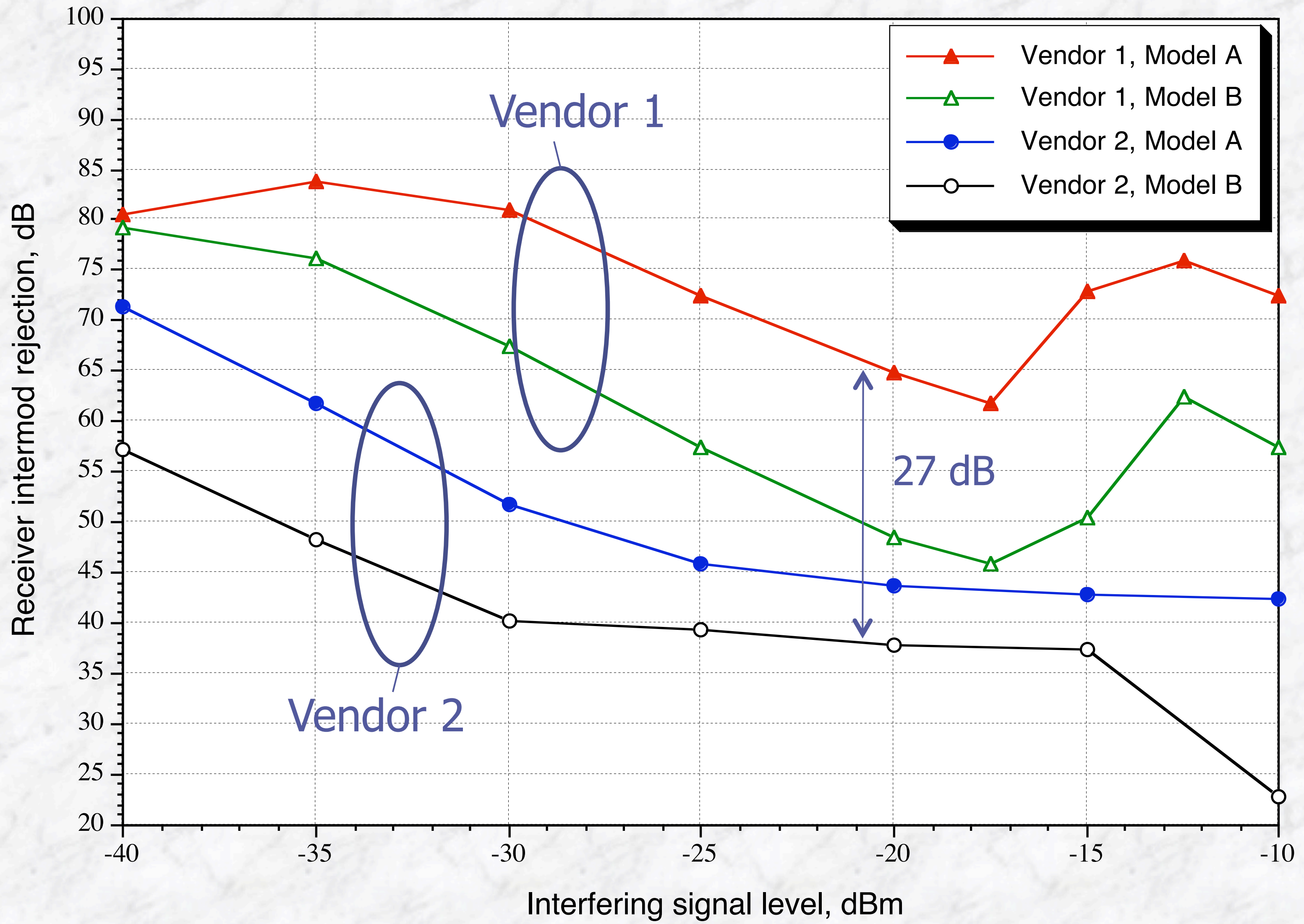
Shortfalls of Existing Standards

- **And TIA-603-D tests do not tell whole story**
  - Maximum interferer level during test is -48 dBm (for portable with -118 dBm sensitivity and 70 dB ACR)
  - Interferers are often at -10 dBm on the street

- **Other tests are needed to characterize radio**
  - Strong signal IM rejection
  - Overload rejection
  - Image rejection

- **Are broadband cellular signals different?**
  - Yes, but overall peak power and IM power are most important.
  - For same ERP, broadband has lower power density which helps the problem with regard to RX IM.
  - High peak-to-average ratio: receiver will respond to the peak power in the signal, so interference specs should be referenced to and tested with peak power.

Strong Signal IM Examples



What do SSIM Results Mean?

- **Example #1 – Vendor 2, Model B: If two equal power interferers hit antenna port at -20 dBm, desired signal must be no less than 38 dB below this level, or -58 dBm.**

- **Example #2 – Vendor 1, Model A: If two equal power interferers hit antenna port at -20 dBm, desired signal must be no less than 65 dB below, or -85 dBm.**

- **How many systems have a -58 dBm signal over a large percentage of the coverage area?**

- **We can use SS IM bench performance to help troubleshoot problems in the field. It tells us how strong the desired signal must be to overcome interference.**

Unequal Power Interferers

- **Measurements usually done with equal power interferers.**
- **In field, interferers often unequal power, e.g.,**
  - Sprint-Nextel at -20 dBm
  - Cellular A operator at -60 dBm (filtered in receiver front end)
- **Fortunately, simple expression applies for two-tone, third order:**

$$P_{IM-Equiv} = \frac{2P_{strongest} + P_{weakest}}{3}$$

- **For our example, equal power equivalent is -33 dBm which is still strong.**
- **Lesson: Spend your time reducing power of strongest interferer.**

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Mitigation Techniques

- **Work with Cellular Operator(s)**
  - Identify the offending site
  - Perform on/off testing to isolate problem
  - Be aware it may be Sprint Nextel *and* A band operator

- **Possible Short Term Solutions**
  - Retune for IM (hard to do with broadband signals)
  - Reduce output power (works, but operator will object)
  - Move antennas away from roof edge
  - Replace cell site antennas with no-null fill type
  - Change beamtilt of cell site antennas (mixed results)
  - Install bandpass filters on mobiles (easy, but not free)
  - Insert bandpass filter in portable antenna radome (problematic)
  - Replace public safety radios with better performers

Field Work in Oakland, CA

- **Oakland is 3-site P25 simulcast system by Harris**
  - Mobiles M7200
  - Portables P7100 and P7200
  - At least one XG-75 also tested in field
  - System has been rebanded, now 851-855 MHz
  - Sprint Nextel is ESMR operator AT&T is A-band operator
  - Roughly 150 AT&T sectors in Oakland PSAP region
  - Number of sites varies (2-3 sectors per site)

- **Status As of Jan 21, 2013**
  - 43 locations visited
  - 13 AT&T sites showed no problem (pre-emptive)
  - 5 sites Nextel mitigated
  - 2 sites complicated by public safety site repeater interference
  - 1 site Nextel and AT&T both mitigated
  - 3 sites signal too low or excessive multipath
  - 20 sites AT&T mitigated (1 beamtilt, 19 reduced power)

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Is This a Widespread Problem?

- **Must Be**
  - Nothing unique about Oakland or Charleston County
- **Characteristics of Problem Cities**
  - Urban area with low cellular antenna heights
  - Public safety signal adequate, but not super strong (< -60 dBm)
  - Modern, but perhaps not best performing public safety radios
- **Given the limitations of typical public safety radios and the strong interfering signals on the street, we expect this to be a widespread problem.**

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What is Changing?

- **A-Band Operator is Adding More RF Carriers**
  – New LTE carriers have high peak to average ratio

- **Sprint Nextel**
  – New CDMA & LTE carriers in 862-869 MHz band
  – After long idle period in this band
  – Be on lookout for strong signal IM and blocking problems

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Long Term — Better RX Stds.

- **The main problem is the portable bandpass filter**
  - Until recently it had to pass 851-869 MHz
  - Practical filters typically pass 845-875 MHz
  - Little motivation to unilaterally change filters due to added cost and logistics of managing a US-only product line (and lingering issues in border regions).

- **Need a 851-861 MHz filter for public safety band**
  - Should it be mandated like Part 90.672?
  - If so, what is the transition period?
  - Filter is not foolproof and poorly designed receivers might still see problems. Should minimum strong signal IM performance also be specified in Part 90.672?

- **Part of a bigger FCC initiative**
  - See ET Docket 13-101

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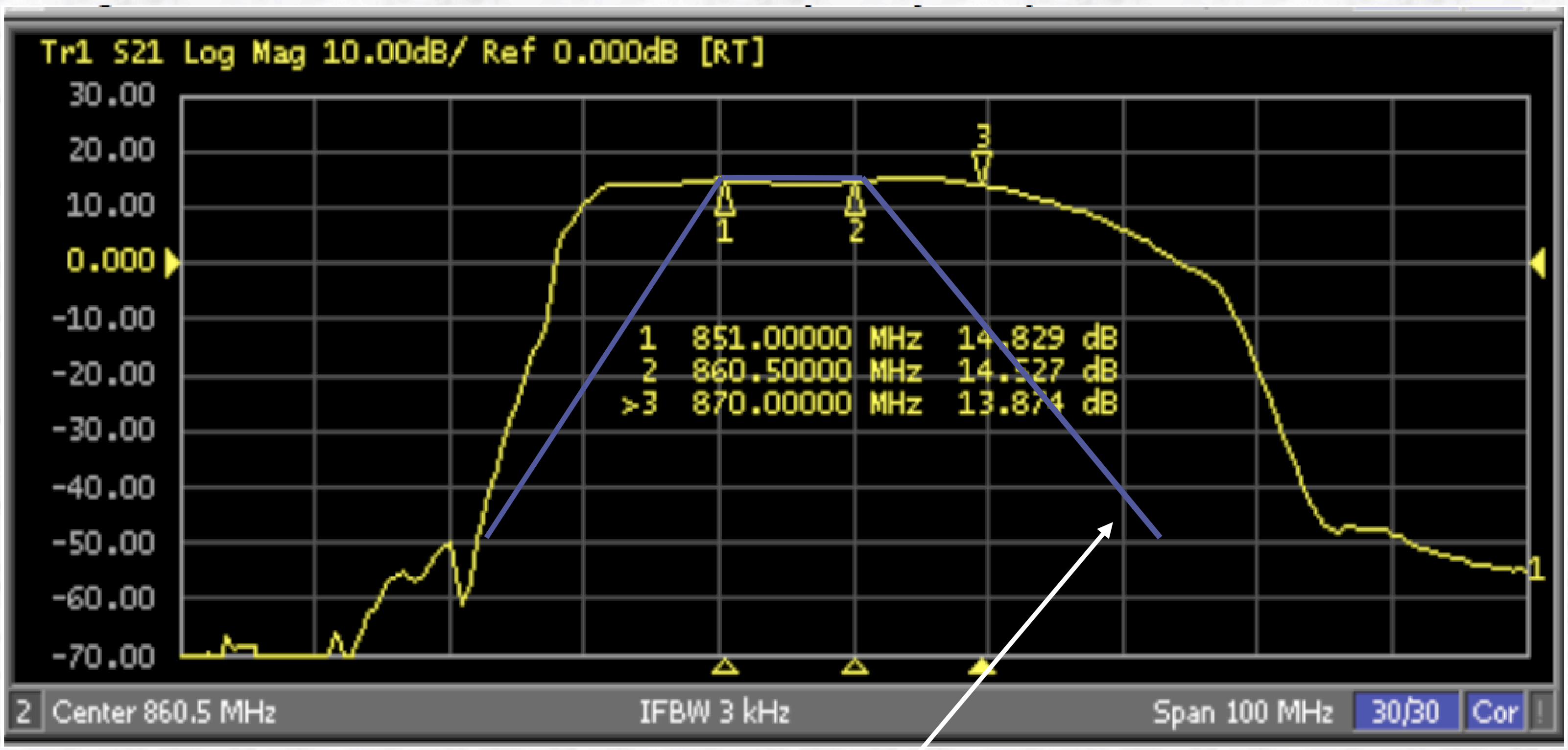
Typical Portable Band Pass Filter

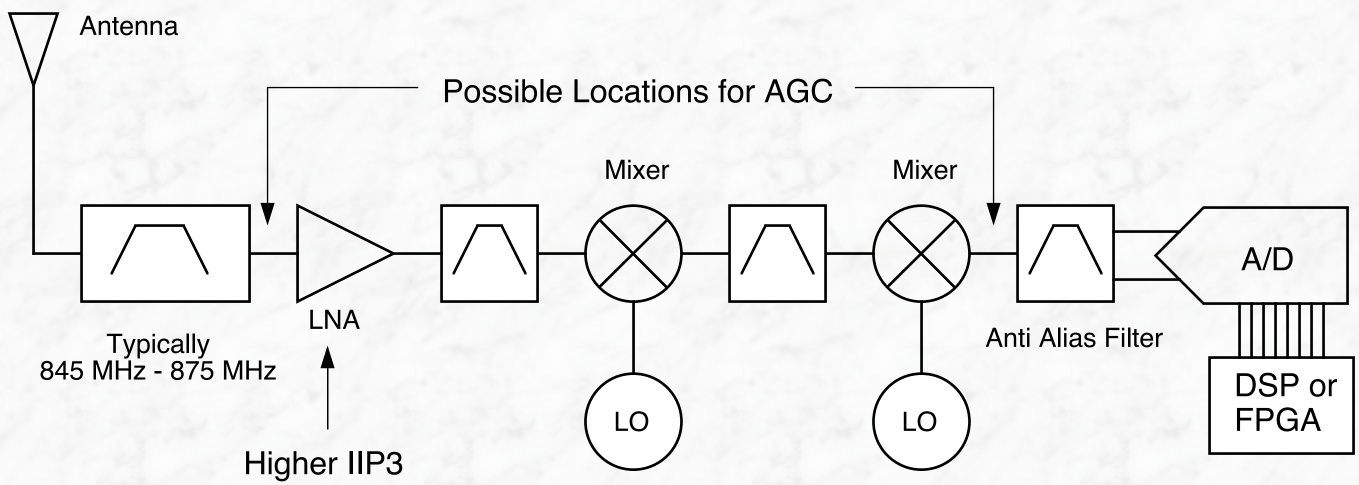


Desired Post-Reband Filter
850-860 MHz

Also Non-Filter Solutions

- **Higher IIP3 LNA**
  - E.g., results in 80 dB IMR per TIA-603 versus 70 dB
  - Tradeoff with battery life

- **One or Two Attenuators for AGC**
  - Switch attenuators in or out depending on detected signal



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Conclusions

- **Rebanding alone does not solve entire problem**
  - Bandpass filters and/or better receivers are needed now
- **Sprint-Nextel conversion to CDMA/LTE is potential problem**
  - Broadband, high peak-to-average signal
  - Cell site "tuning" no longer possible for RX IM
  - Mitigated by lower power density for RX IM
- **Receiver performance varies dramatically**
  - Between models of the same vendor
  - Between different vendors
- **RFP requirements not adequate**
  - Strong signal IM performance is not specified or required in RFPs, but should be

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