Taking the Guesswork out of RF Specifications

January 2024

Electronics

Helicopters

Aircraft

Cyber &
Security

Space

Unmanned
Systems

Aerostructures

Who Leonardo DRS - Signal Solutions is

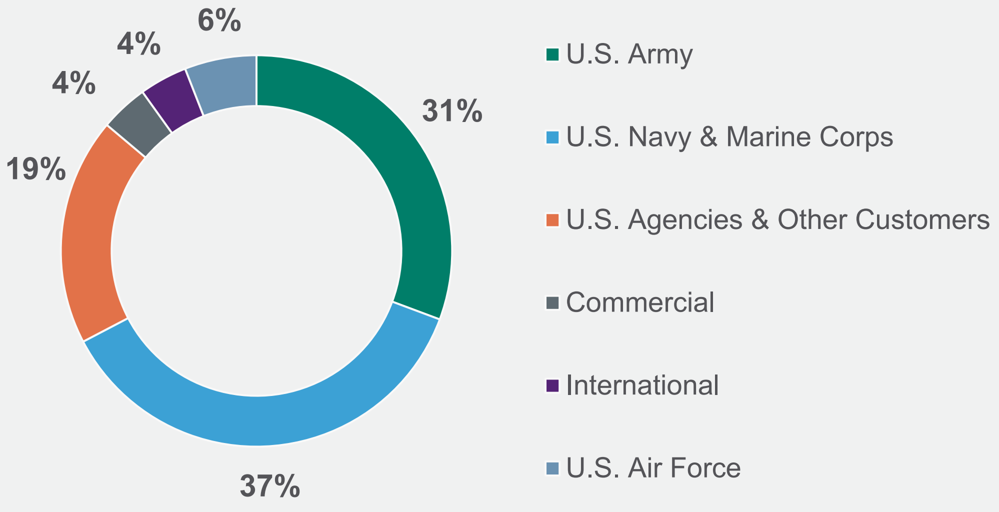
AN OVERVIEW OF LEONARDO DRS

A leading mid-tier technology innovator and provider of advanced defense technology to U.S. national security customers and allies around the world. We design, develop and manufacture advanced sensing, network computing, force protection, electric power and propulsion, and other leading mission-critical technologies.

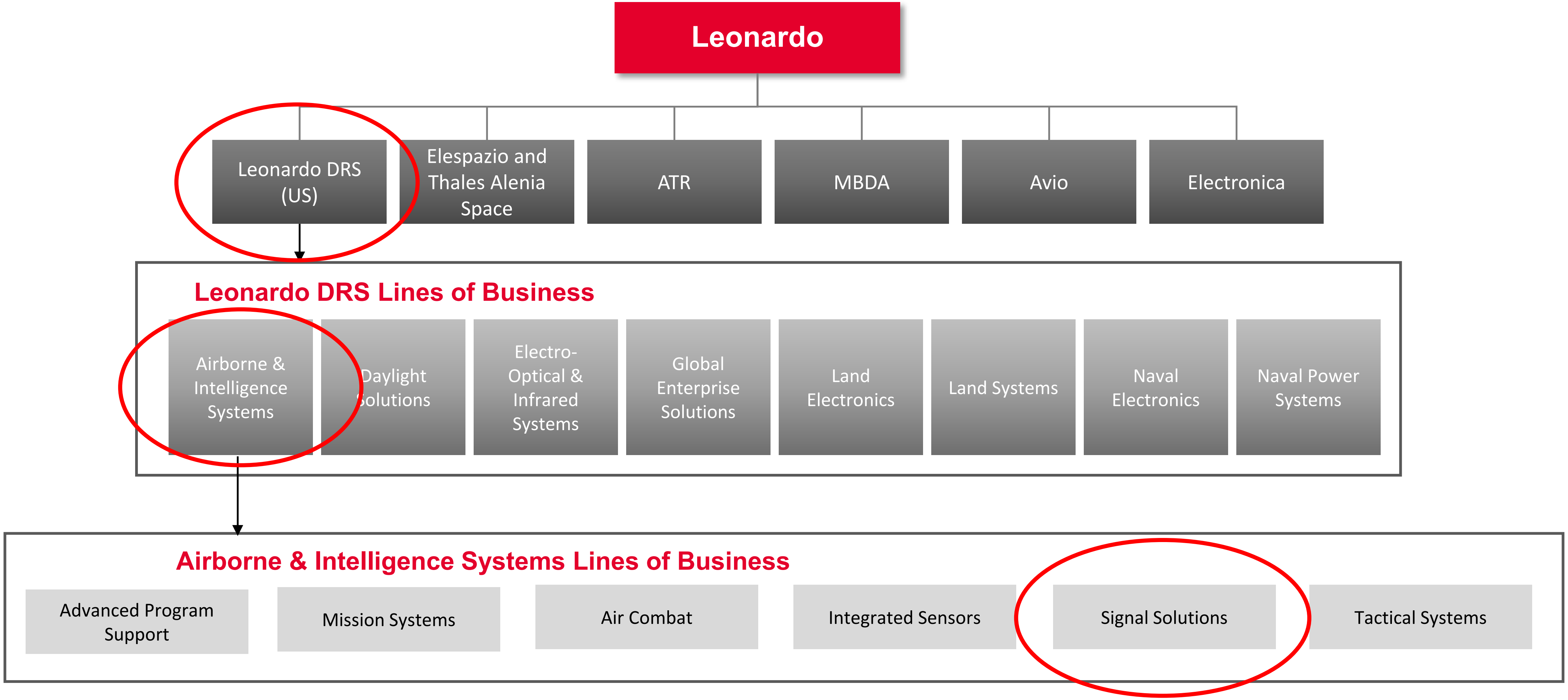
- Largest U.S. defense proxy company headquartered in Arlington, Virginia and organized into two segments:
  - Advanced Sensing & Computing
  - Integrated Mission Systems
- Continuing to grow through strategic investments in technology and capabilities.
- Publicly traded company on the U.S. and Israel Stock exchanges.

DRS | Nasdaq Listed

BUSINESS MIX BY CUSTOMER

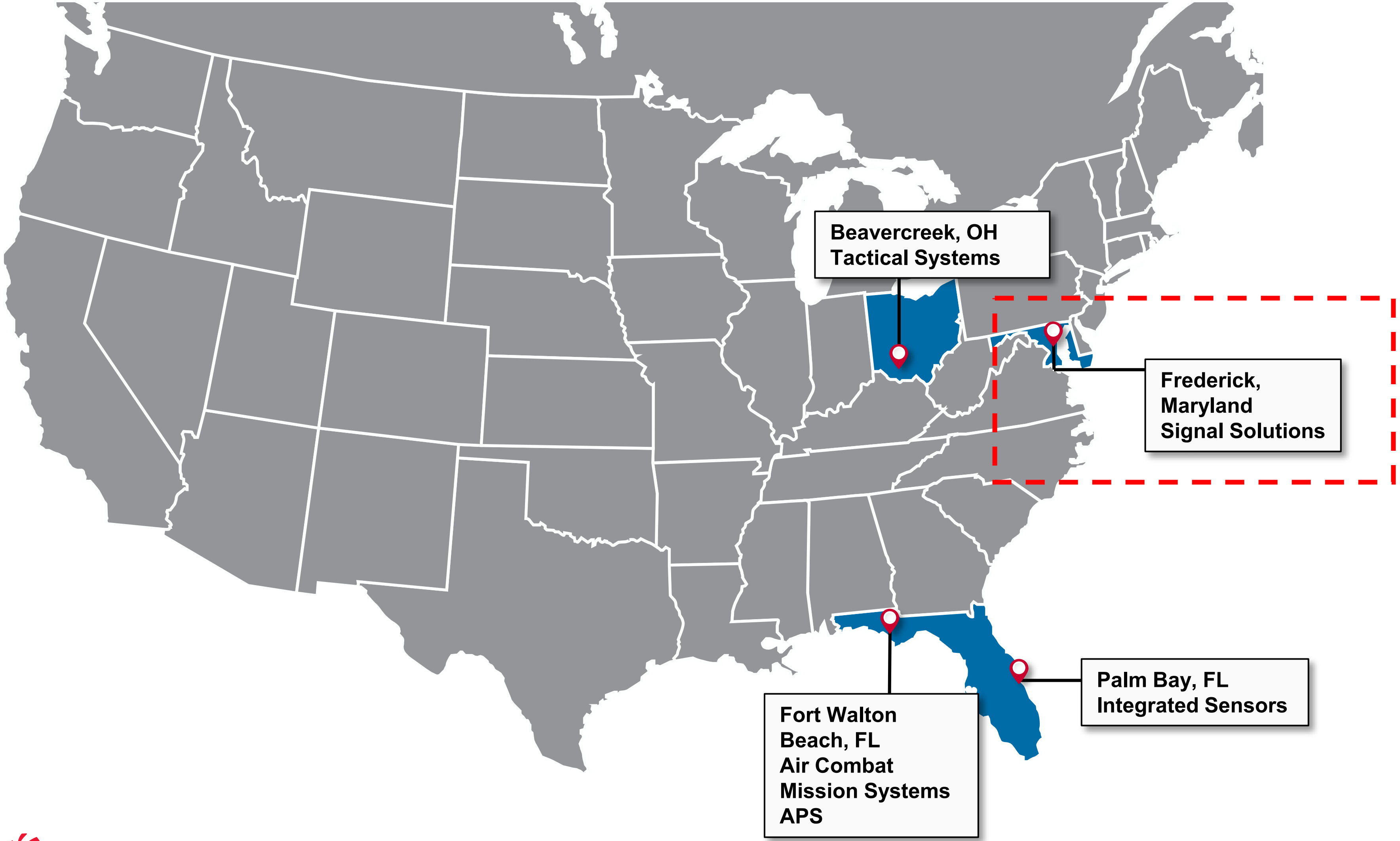


Company Structure



DRS AIS AT A GLANCE

A Proven Leader in Airborne & Intelligence Products, Technologies and Integrated Solutions



- ~700 Employees
- 50+ years in providing warfighter solutions
- Customer-Accredited Space
- ISO 9001 Certified
- CMMI Level 3 Certified
- AS 9100

RF Provider Of Choice

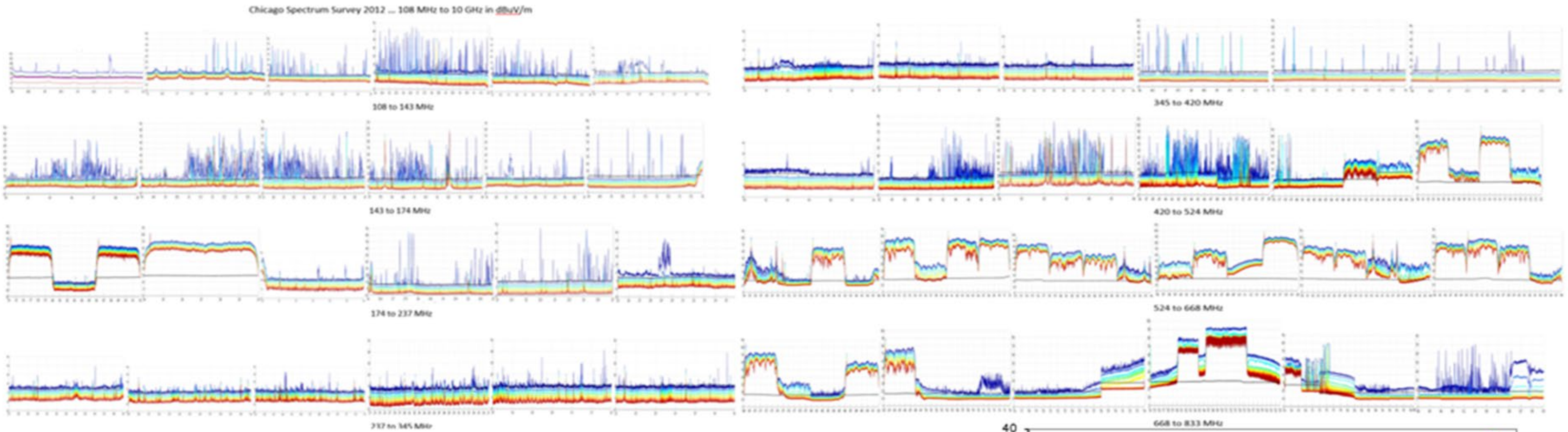
Industry Leading RF Performance and Signal Fidelity - Enabling Mission Flexibility

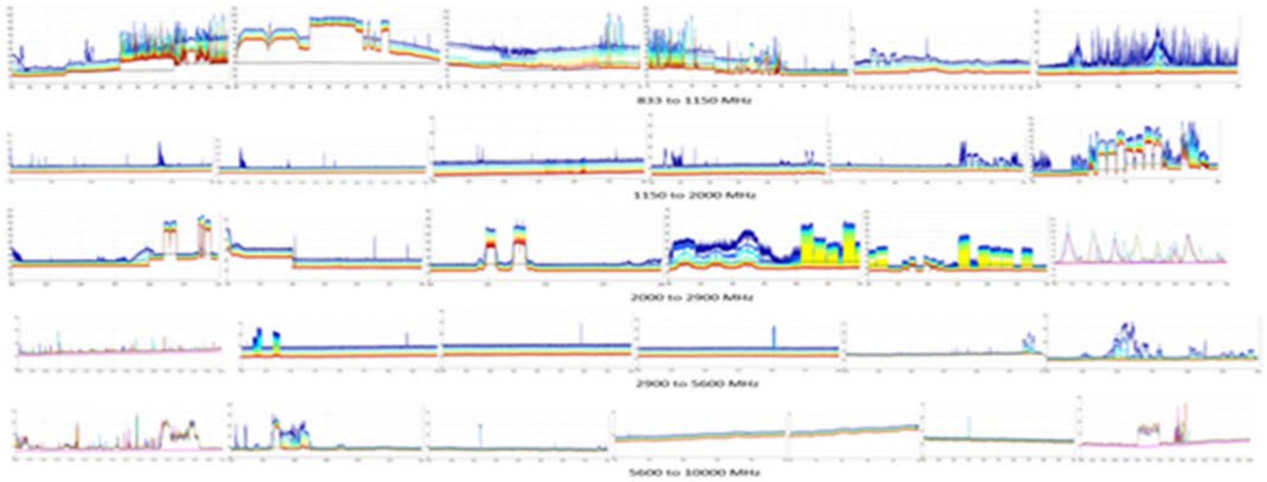
- Extended Frequency Ranges
- Wider Instantaneous Bandwidths
- **Increased Dynamic Range – Detect Small Signals in the Presence of Large Interfering Signals**
- **Reduced Spurious – Increase Confidence that Signals are Genuine**
- Greater Channel Density

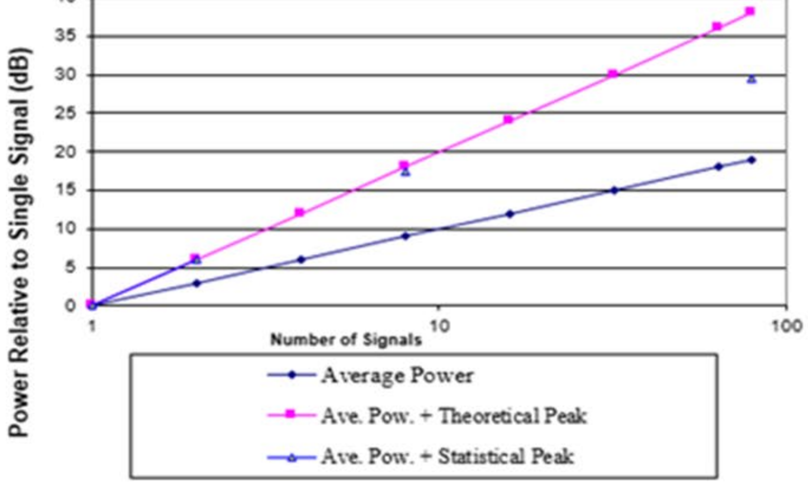
- Ruggedized RF COTS Solutions
- Modular Approaches – Enabling Rapid Technology Upgrades
- Completely Open Standards Based
- Reduced Cost
- Repeatable and Reliable Process Driven Manufacturing

Why Performance Matters

Our World Full of MILLIONS of RF Signals Large and Small







**Chicago Radio Spectrum 108 MHz to 10 GHz*

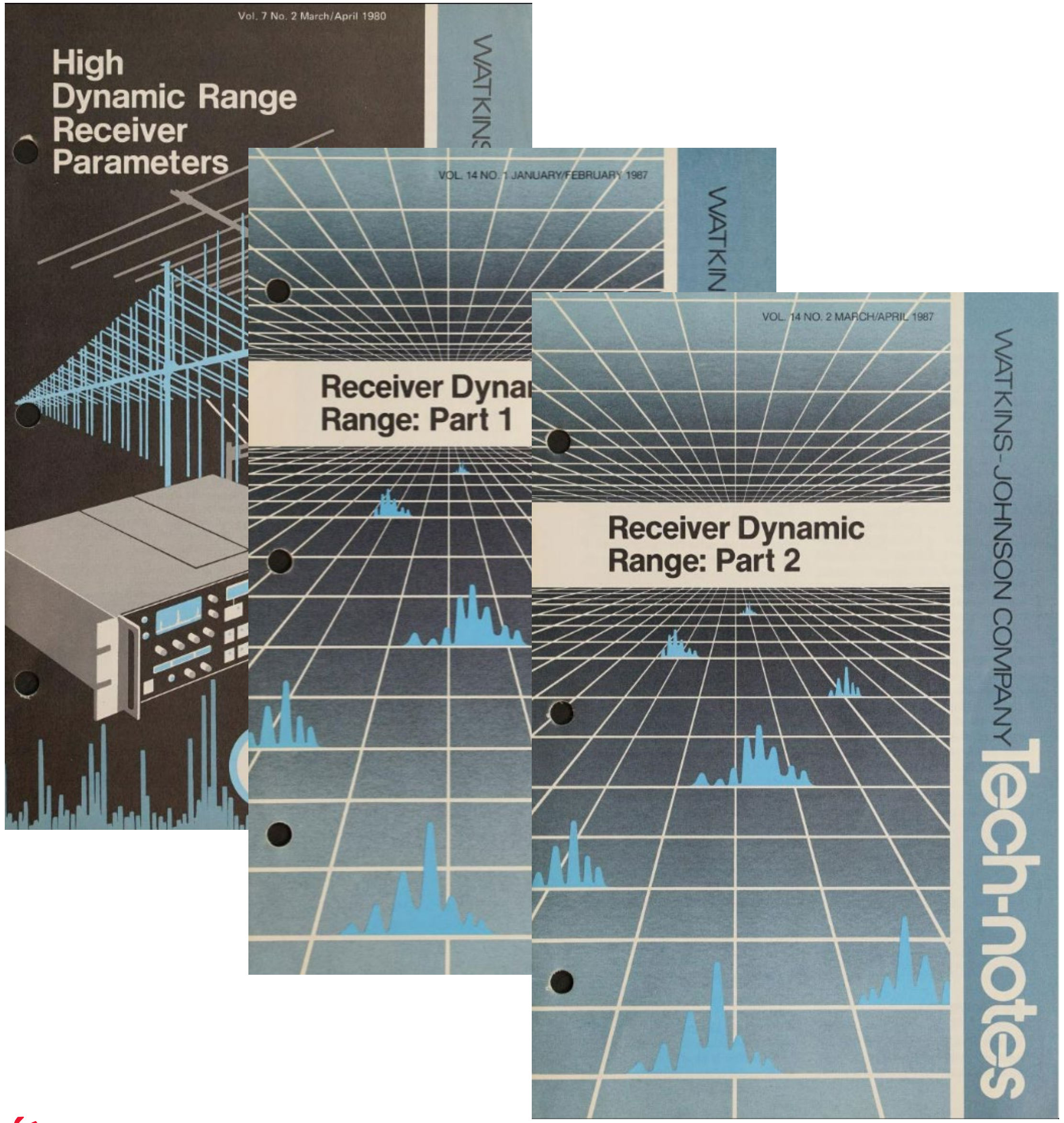
High Dynamic Range Is Essential!

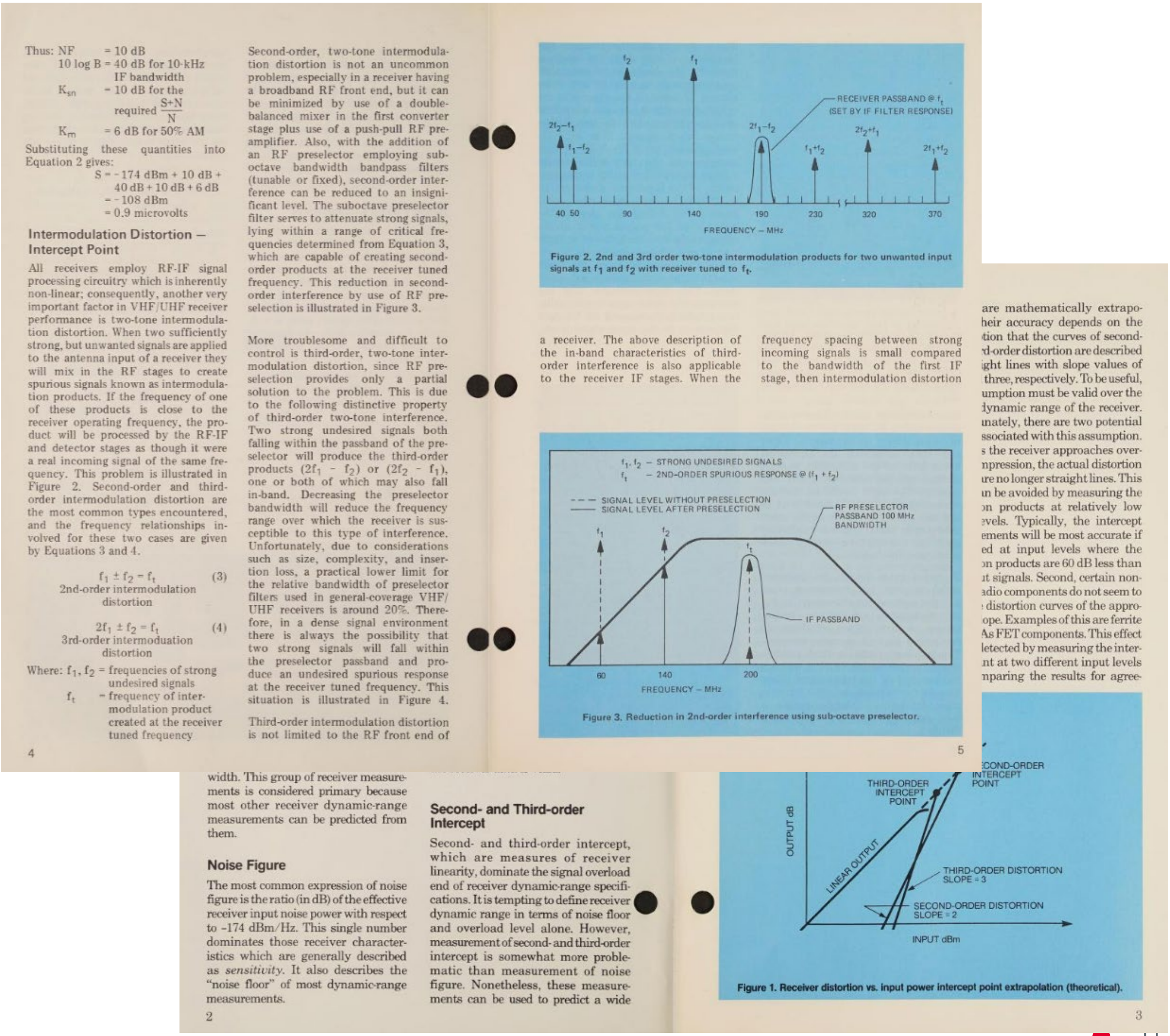
The power ratio of strong interfering signals compared to a small desired signal is often more than **10,000,000,000:1** (i.e. >100 dB)

Dynamic Range!

Everybody wants lots of it…
but most don't know how to specify it!

Watkins Johnson Tech Notes 1974-1991





Thus: NF = 10 dB
10 log B = 40 dB for 10-kHz IF bandwidth
K_{sn} = 10 dB for the required $\frac{S+N}{N}$
K_m = 6 dB for 50% AM

Substituting these quantities into Equation 2 gives:

$$S = -174 \text{ dBm} + 10 \text{ dB} + 40 \text{ dB} + 10 \text{ dB} + 6 \text{ dB} = -108 \text{ dBm} = 0.9 \text{ microvolts}$$

Intermodulation Distortion — Intercept Point

All receivers employ RF-IF signal processing circuitry which is inherently non-linear; consequently, another very important factor in VHF/UHF receiver performance is two-tone intermodulation distortion. When two sufficiently strong, but unwanted signals are applied to the antenna input of a receiver they will mix in the RF stages to create spurious signals known as intermodulation products. If the frequency of one of these products is close to the receiver operating frequency, the product will be processed by the RF-IF and detector stages as though it were a real incoming signal of the same frequency. This problem is illustrated in Figure 2. Second-order and third-order intermodulation distortion are the most common types encountered, and the frequency relationships involved for these two cases are given by Equations 3 and 4.

$$f_1 \pm f_2 = f_t \quad (3)$$
2nd-order intermodulation distortion

$$2f_1 \pm f_2 = f_t \quad (4)$$
3rd-order intermoduation distortion

Where: f_1, f_2 = frequencies of strong undesired signals
f_t = frequency of intermodulation product created at the receiver tuned frequency

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Second-order, two-tone intermodulation distortion is not an uncommon problem, especially in a receiver having a broadband RF front end, but it can be minimized by use of a double-balanced mixer in the first converter stage plus use of a push-pull RF preamplifier. Also, with the addition of an RF preselector employing sub-octave bandwidth bandpass filters (tunable or fixed), second-order interference can be reduced to an insignificant level. The suboctave preselector filter serves to attenuate strong signals, lying within a range of critical frequencies determined from Equation 3, which are capable of creating second-order products at the receiver tuned frequency. This reduction in second-order interference by use of RF preselection is illustrated in Figure 3.

More troublesome and difficult to control is third-order, two-tone intermodulation distortion, since RF preselection provides only a partial solution to the problem. This is due to the following distinctive property of third-order two-tone interference. Two strong undesired signals both falling within the passband of the preselector will produce the third-order products $(2f_1 - f_2)$ or $(2f_2 - f_1)$, one or both of which may also fall in-band. Decreasing the preselector bandwidth will reduce the frequency range over which the receiver is susceptible to this type of interference. Unfortunately, due to considerations such as size, complexity, and insertion loss, a practical lower limit for the relative bandwidth of preselector filters used in general-coverage VHF/UHF receivers is around 20%. Therefore, in a dense signal environment there is always the possibility that two strong signals will fall within the preselector passband and produce an undesired spurious response at the receiver tuned frequency. This situation is illustrated in Figure 4.

Third-order intermodulation distortion is not limited to the RF front end of

Figure 2. 2nd and 3rd order two-tone intermodulation products for two unwanted input signals at f_1 and f_2 with receiver tuned to f_t.

a receiver. The above description of the in-band characteristics of third-order interference is also applicable to the receiver IF stages. When the frequency spacing between strong incoming signals is small compared to the bandwidth of the first IF stage, then intermodulation distortion

Figure 3. Reduction in 2nd-order interference using sub-octave preselector.

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width. This group of receiver measurements is considered primary because most other receiver dynamic-range measurements can be predicted from them.

Noise Figure

The most common expression of noise figure is the ratio (in dB) of the effective receiver input noise power with respect to -174 dBm/Hz. This single number dominates those receiver characteristics which are generally described as *sensitivity*. It also describes the "noise floor" of most dynamic-range measurements.

Second- and Third-order Intercept

Second- and third-order intercept, which are measures of receiver linearity, dominate the signal overload end of receiver dynamic-range specifications. It is tempting to define receiver dynamic range in terms of noise floor and overload level alone. However, measurement of second- and third-order intercept is somewhat more problematic than measurement of noise figure. Nonetheless, these measurements can be used to predict a wide

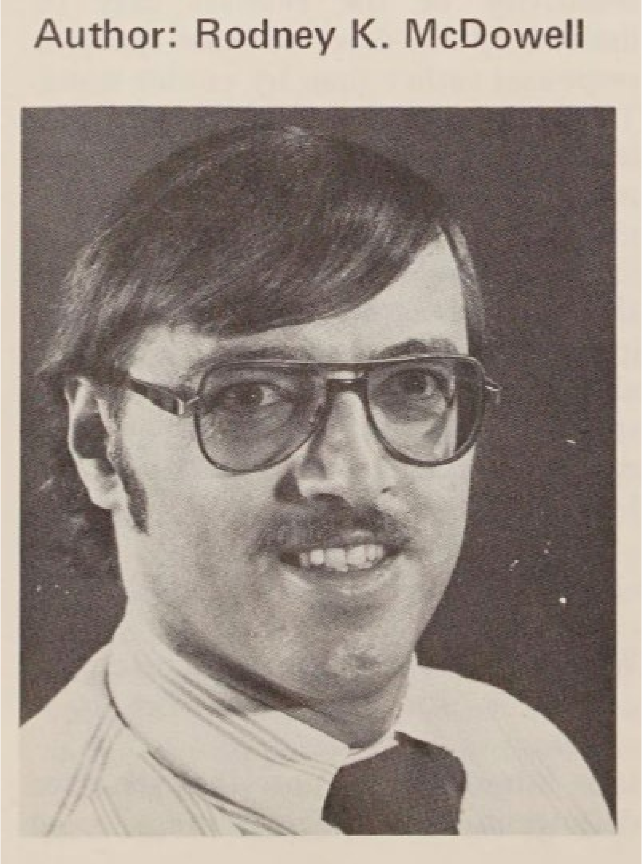
2

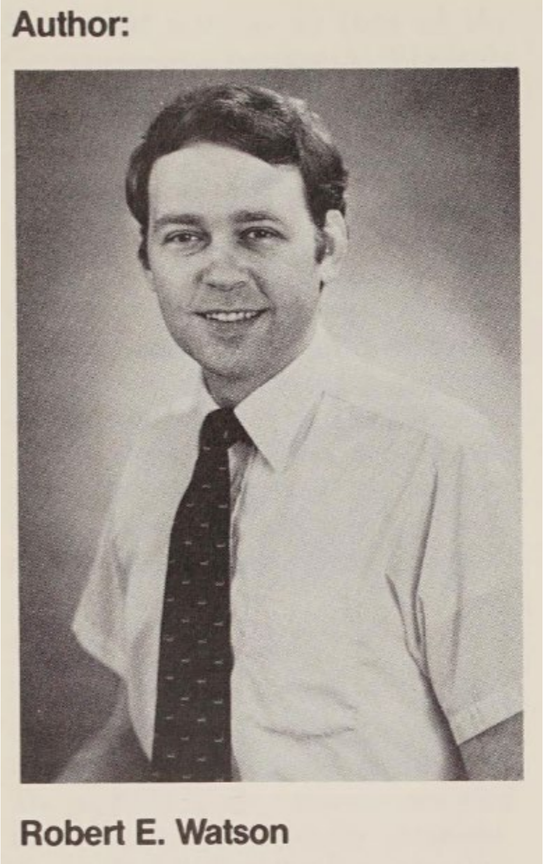
Figure 1. Receiver distortion vs. input power intercept point extrapolation (theoretical).

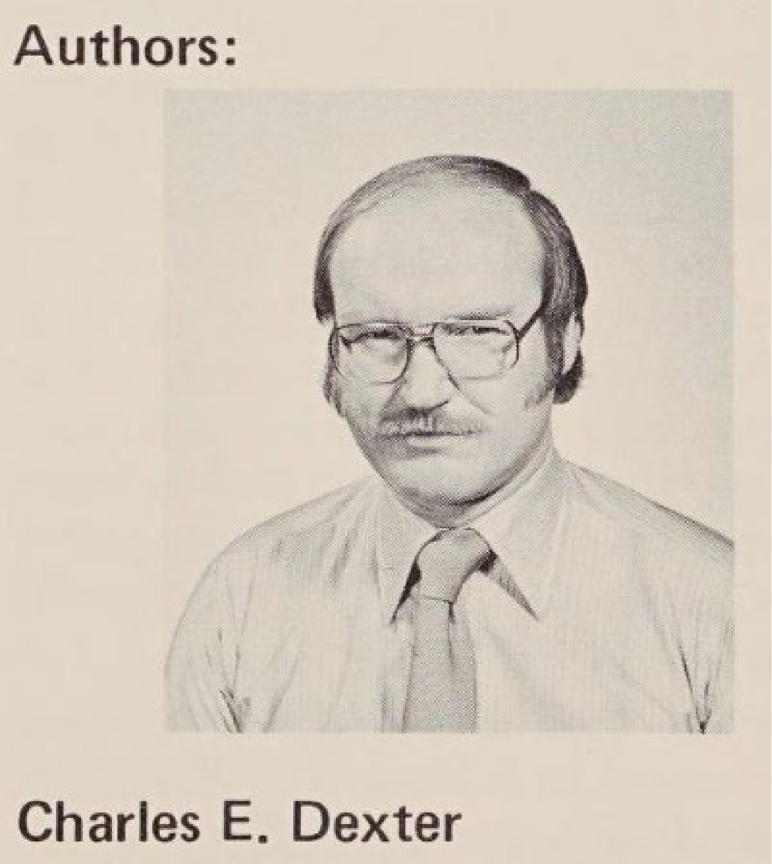
3

Generational Transition - Stand on the Shoulders of Those Before Us

We can go back to basics without starting over.







Some Specifications

Sensitivity
Second Order Intercept
Intermodulation
Alias Rejection
Cross Modulation
ENOB
Error Vector Magnitude
Spur Free Dynamic Range
Noise Figure
1dB Compression
Blocking
Third Order Intercept
IF Rejection
Reciprocal Mix
Overload Recovery
Instantaneous Dynamic Range
Image Rejection
Noise Power Ratio

Some Specifications Are Relatively Useless

And Some Specs are Insufficient: “A Red Car”

Capability Demanded

Identifying and locating signals in a congested environment

Big Three Key RF Specifications (in Service of Capability)

1. **Sensitivity – Standoff Distance**
2. **Spurious – False Detects**
3. **Overload – Jamming Resistance**

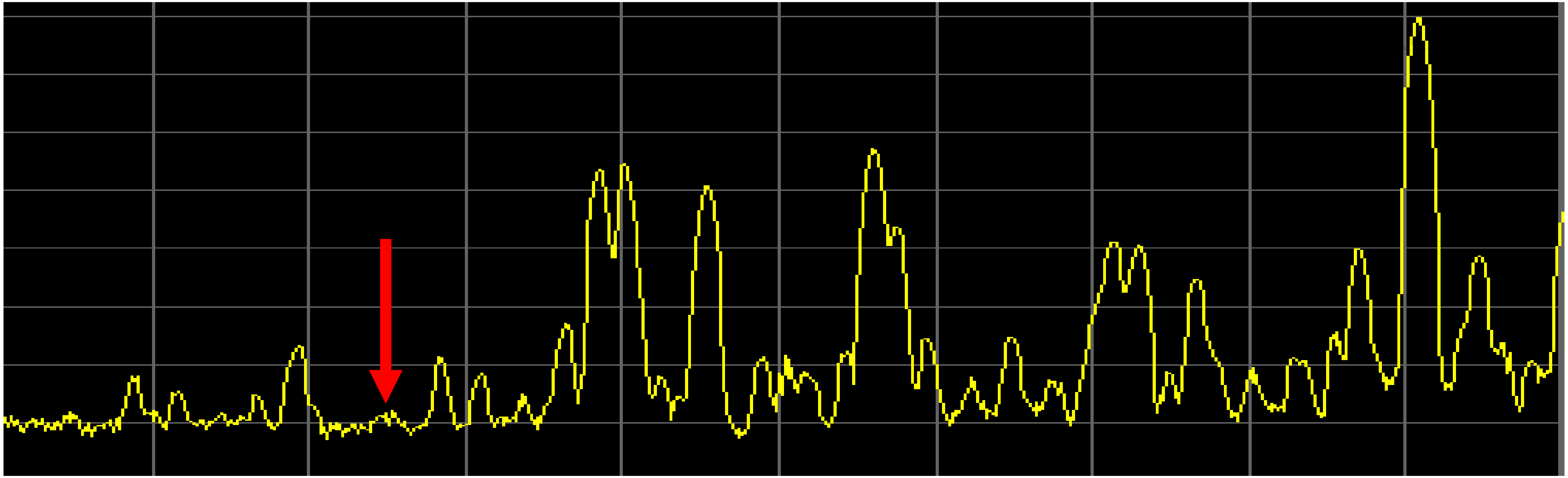
The Radio Goal:

Get the signals you want and...

reject the rest!

What Actually Matters: #1 Sensitivity – Standoff Distance

Sensitivity: Getting the Signal You Want



The Key to Sensitivity is Noise Figure

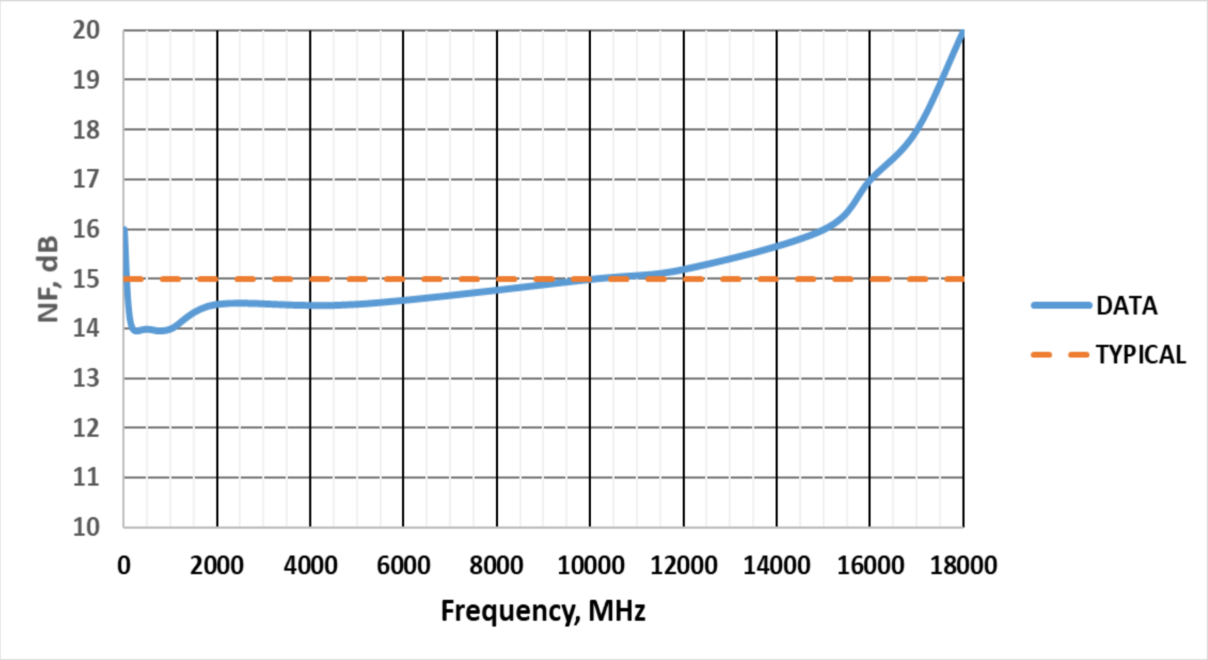
The detectable signal level
in dBm can be calculated from:

$$dBm = NF + SNR + 10 \log (BW) - 174$$

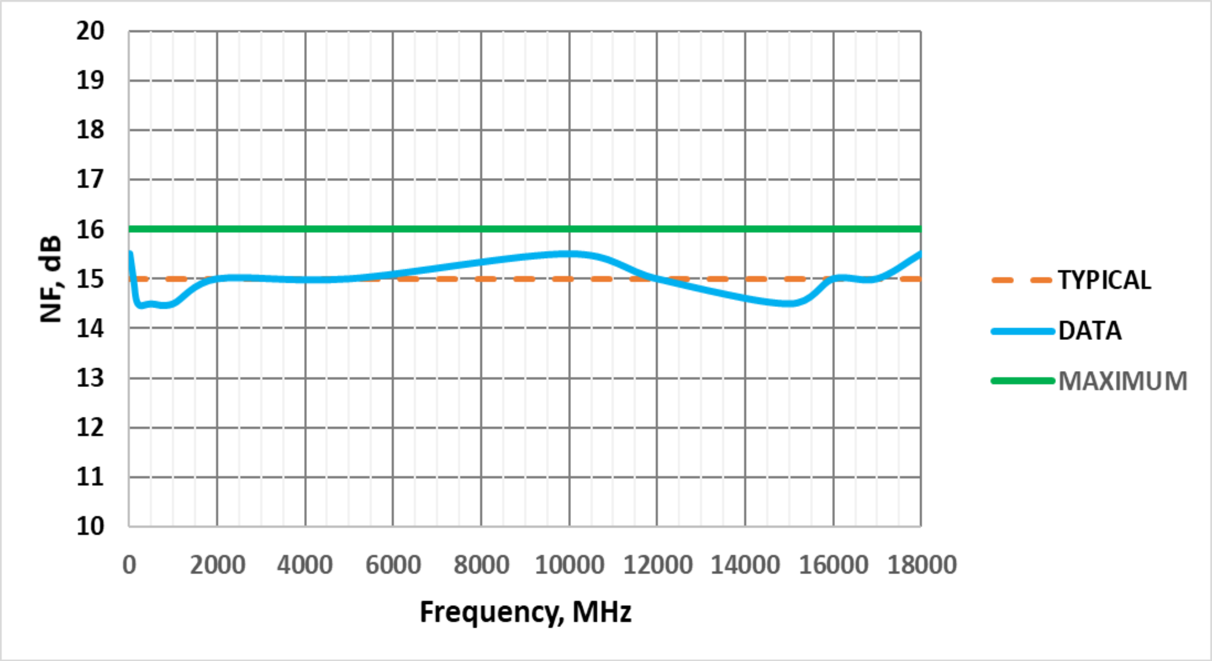
The SNR and bandwidth are signal specific, but noise figure is the key radio specification.

Typical and Maximum Specifications

1. The interpretation of “typical” can be highly variable.
2. A graph of typical data is much more useful.
3. A maximum limit is essential.



Poor Example

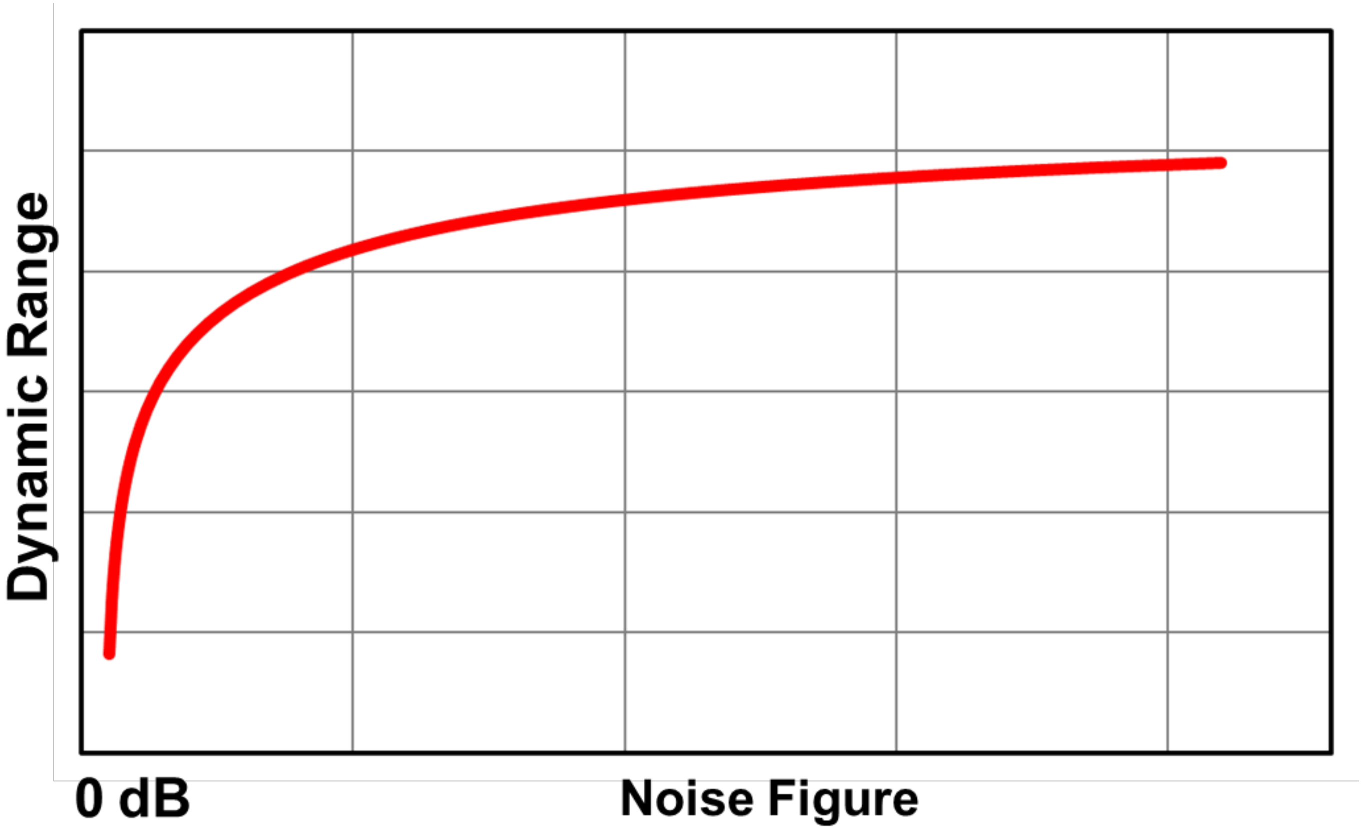


Good Example

Low Noise Figure Has Tradeoffs

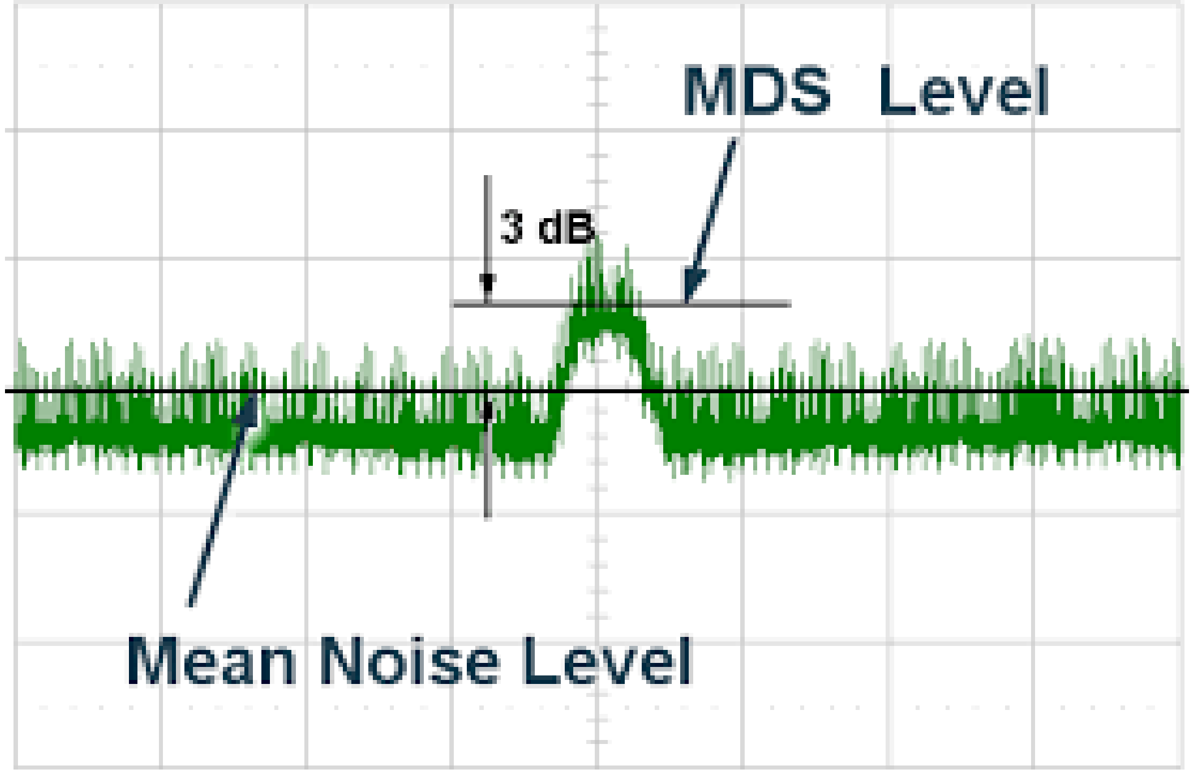
Noise Figure and Dynamic Range need to be balanced to match the task.

- Very low Noise Figure has very poor Dynamic Range.



Minimum Detectable Signal Definition

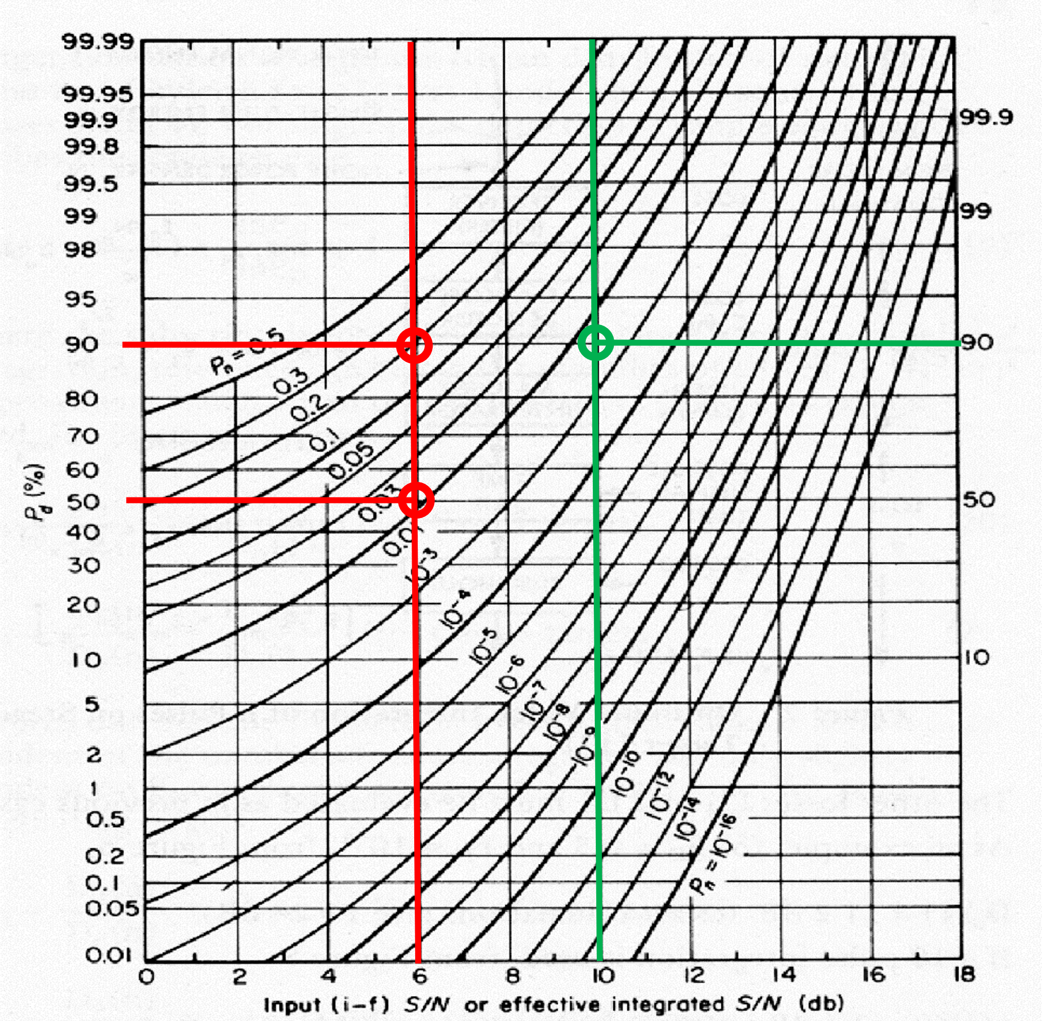
- Detecting signals in noise has a statistical probability.
- With high signal to noise ratio (SNR), the problem is easy.
- **With low SNR the $P_{detection}$ lowers and the $P_{false\ alarm}$ increases**



How Much Signal to Noise Ratio (SNR) Is Required?

The probability of false alarm can be traded for the probability of detection.

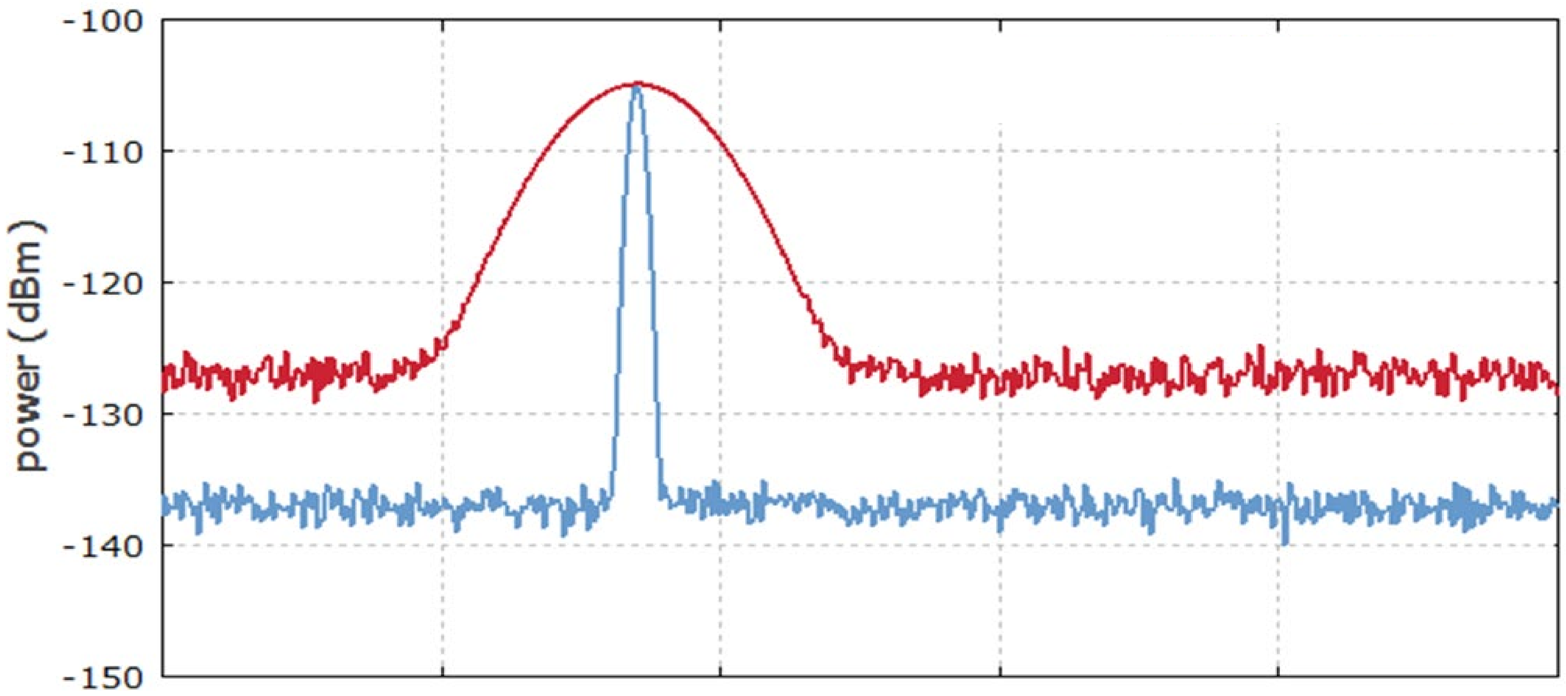
- For a **6 dB** SNR
  - 90% $P_{detection}$ = 20% $P_{false\ alarm}$
  - 50% $P_{detection}$ = 1.0% $P_{false\ alarm}$
- For a **10 dB** SNR
  - 90% $P_{detection}$ = 0.3% $P_{false\ alarm}$



Improving Signal to Noise Ratio (SNR)

In general, the best detection bandwidth is equal to the signal bandwidth.

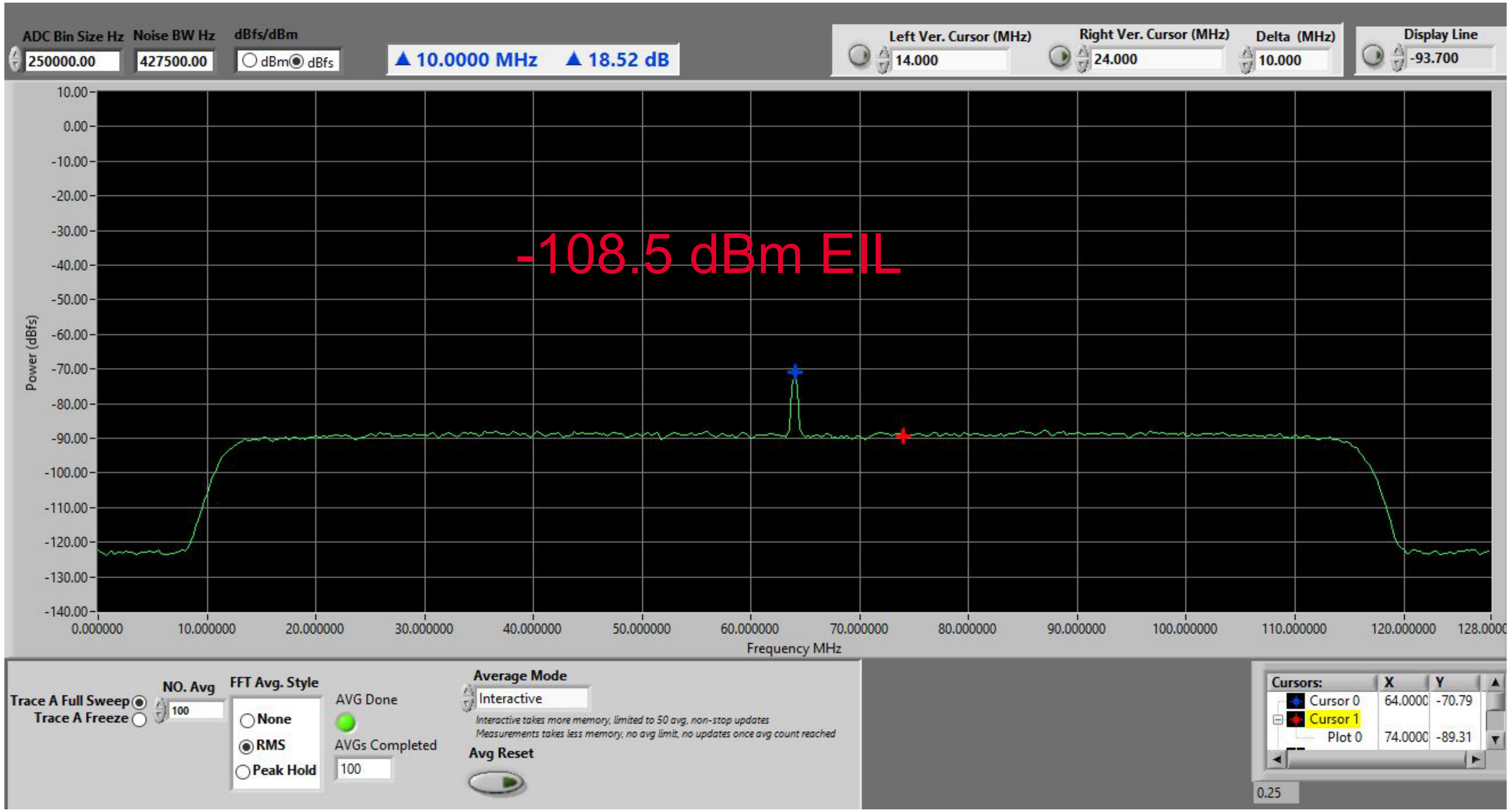
- Reducing bandwidth can improve the Signal to Noise Ratio (SNR).
- This can be achieved with filtering (analog) or with an FFT (digital).



Example 1: Noise Floor Measurement with <u>1k FFT</u>

Measurement Conditions:

- Tuned Frequency = 100MHz
- FFT Size = 1024 points
- Averages = 100 RMS
- Noise BW = 427.5kHz
- Input Signal = -90dBm *+/-1dB*
- Noise Figure = 10dB
- Temperature = +45C Rail



Noise Floor

= -174+NF+10log(BW)

= -174 + 10 + 10log(427500)

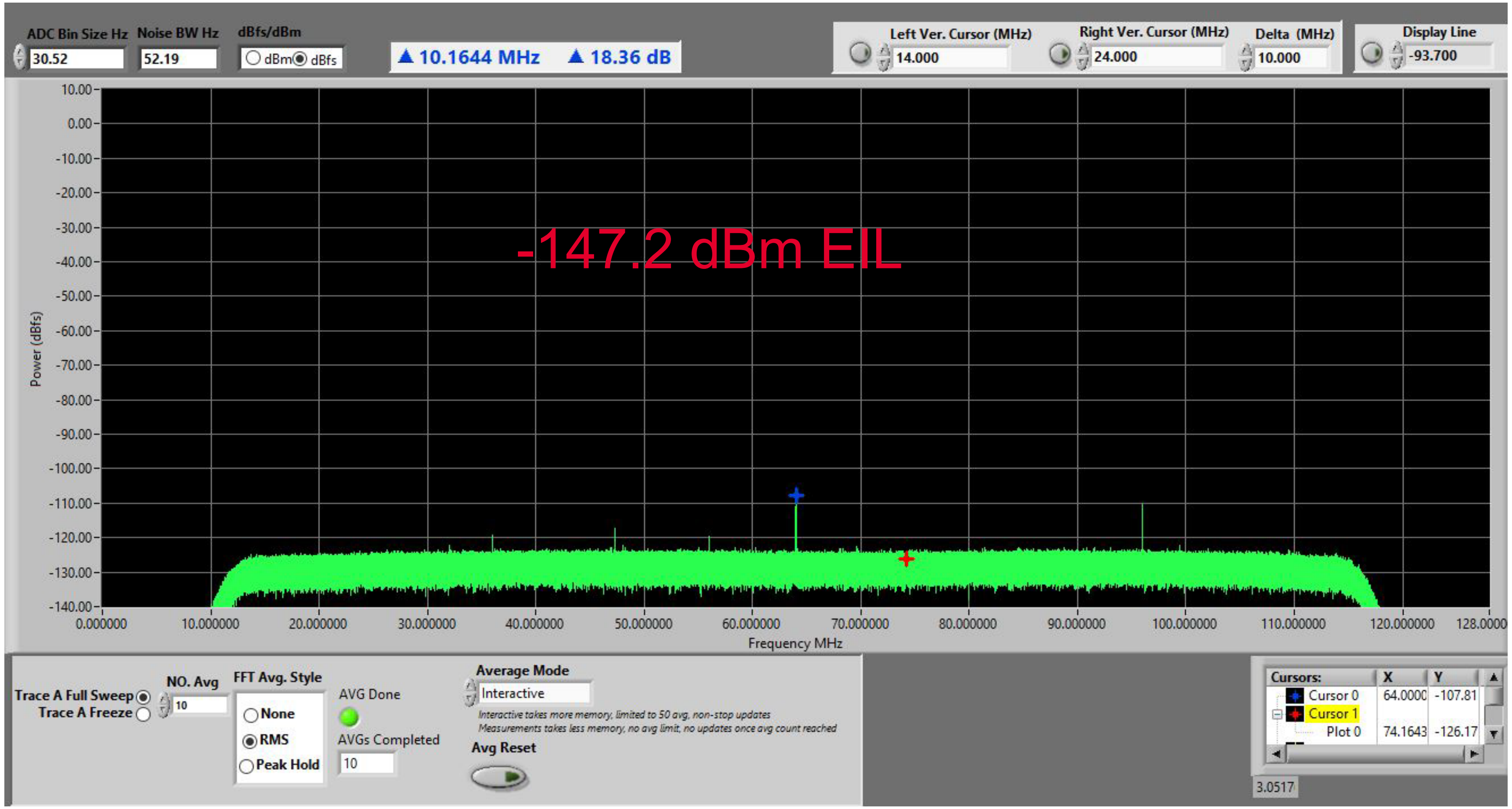
= -107.7 dBm E.I.L.

Example 2: Noise Floor Measurement with 8M FFT

Measurement Conditions:

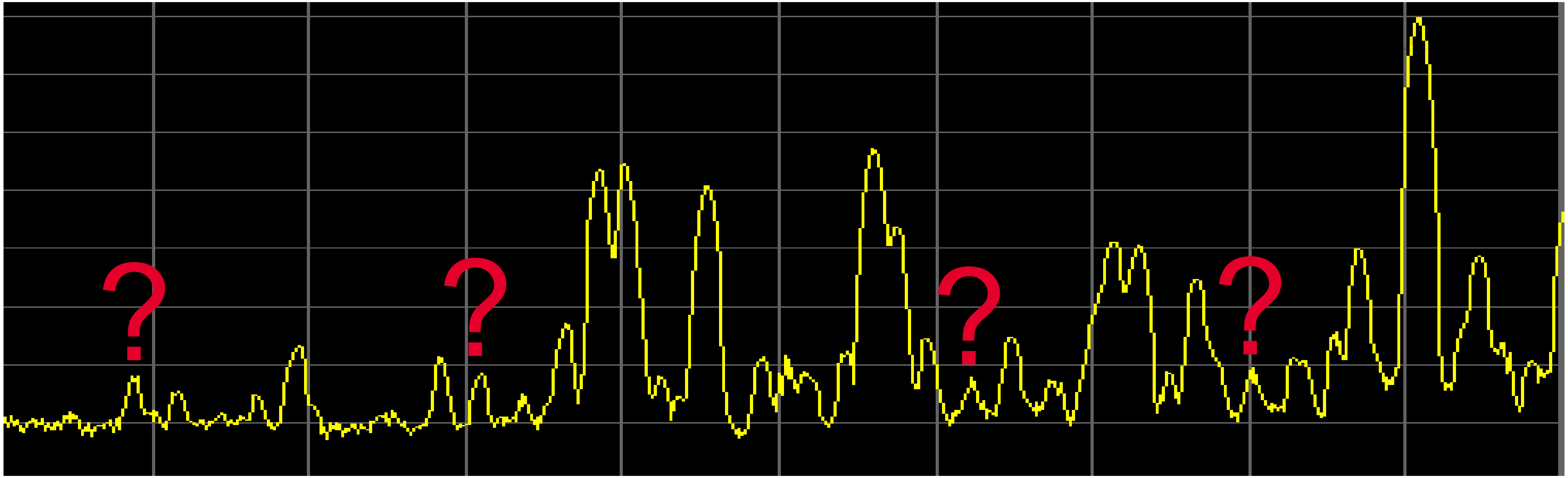
- Tuned Frequency = 100MHz
- FFT Size = 8388608 points
- Averages = 10 RMS
- Noise BW = 52.19Hz
- Input Signal = -130dBm *+/-1dB*
- Noise Figure = 10dB
- Temperature = +45C Rail

Noise Floor
= -174+NF+10log(BW)
= -174 + 10 + 10log(52.19)
= -146.8 dBM E.I.L.



What Actually Matters: #2 Spurious – False Signal Detect

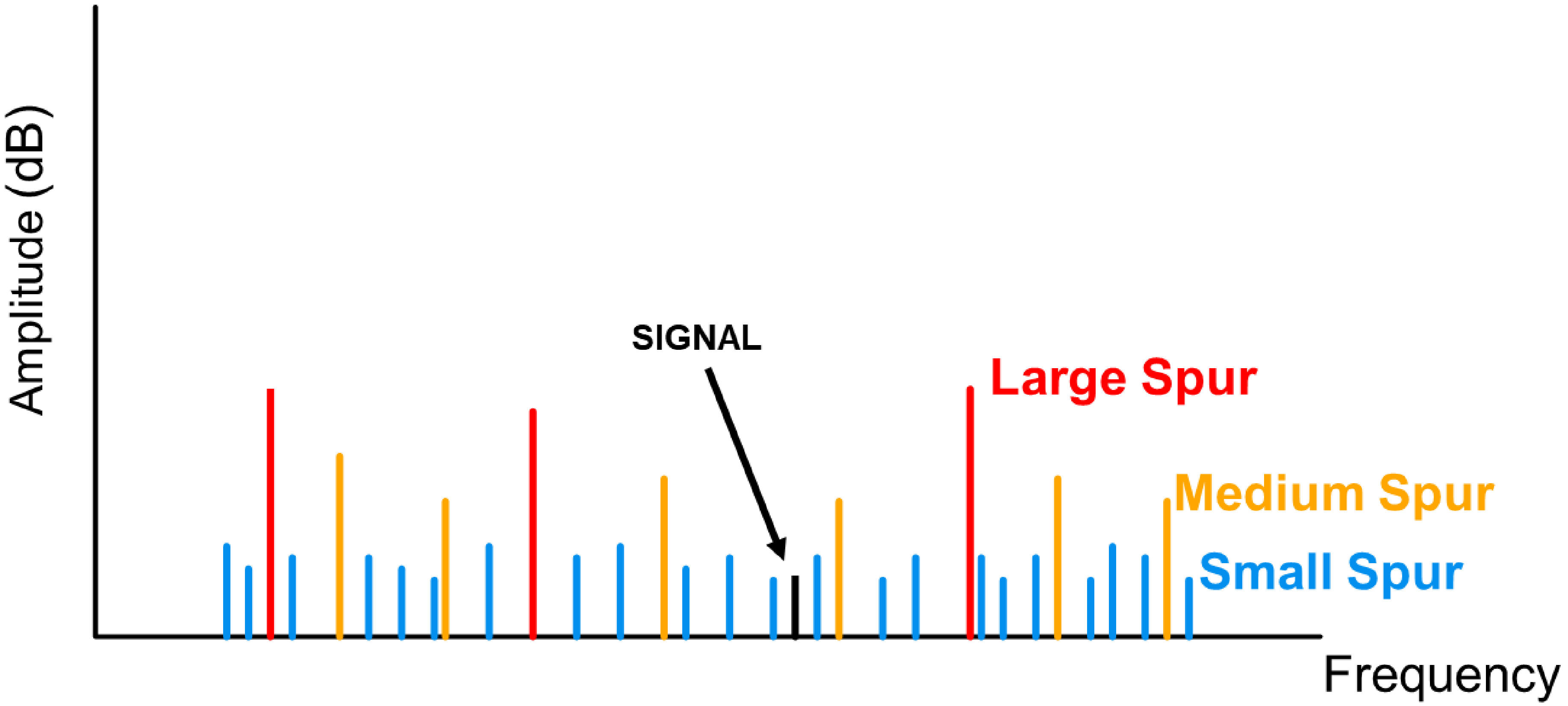
Spurious: Getting the Signal You Want



Internally Generated Spurious Signals

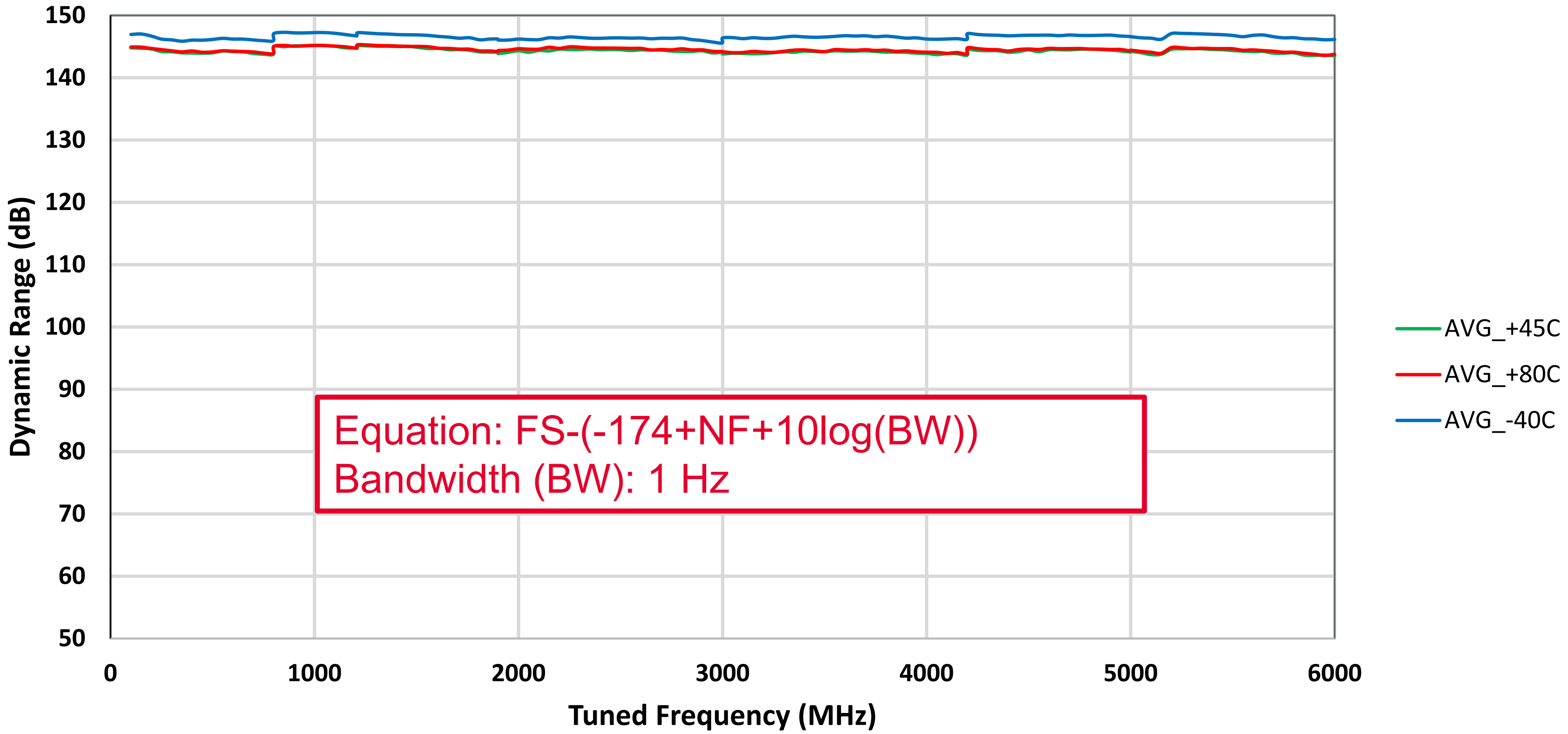
Spurious signals can masquerade as legitimate signals, requiring disambiguation.

Internal spurs may occur at the same frequency as a desired signal, blocking its reception.



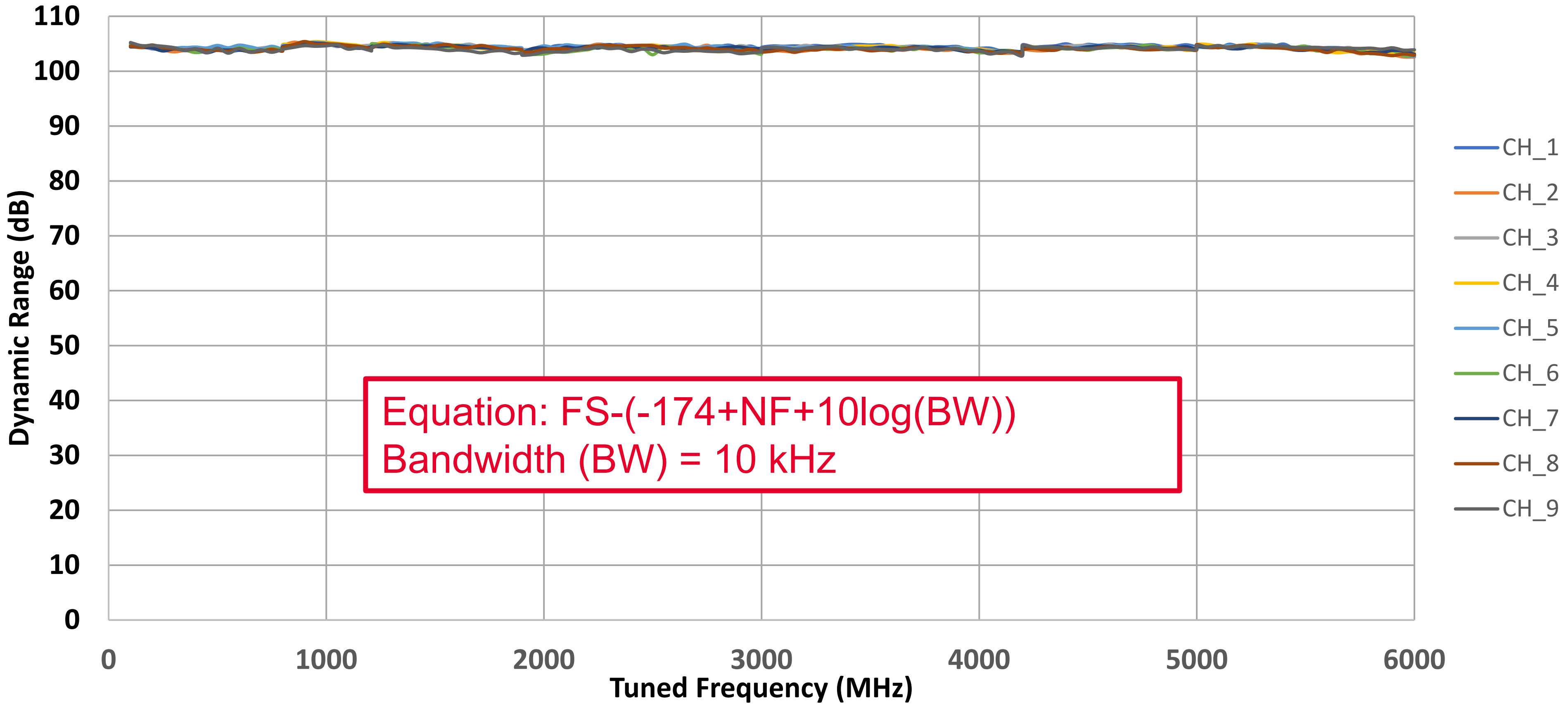
Misleading Instantaneous Dynamic Range – 1 Hz BW

- **The 1Hz BW is not a realistic value as the latency and processing is not practical**
- **The computed values do not consider actual spurious performance**



Accurate Instantaneous Dynamic Range – 10 kHz BW

- **The 10 kHz BW is a realistic value optimizing the SNR for common applications**
- **The computed values are consistent with internally generated spurious performance**

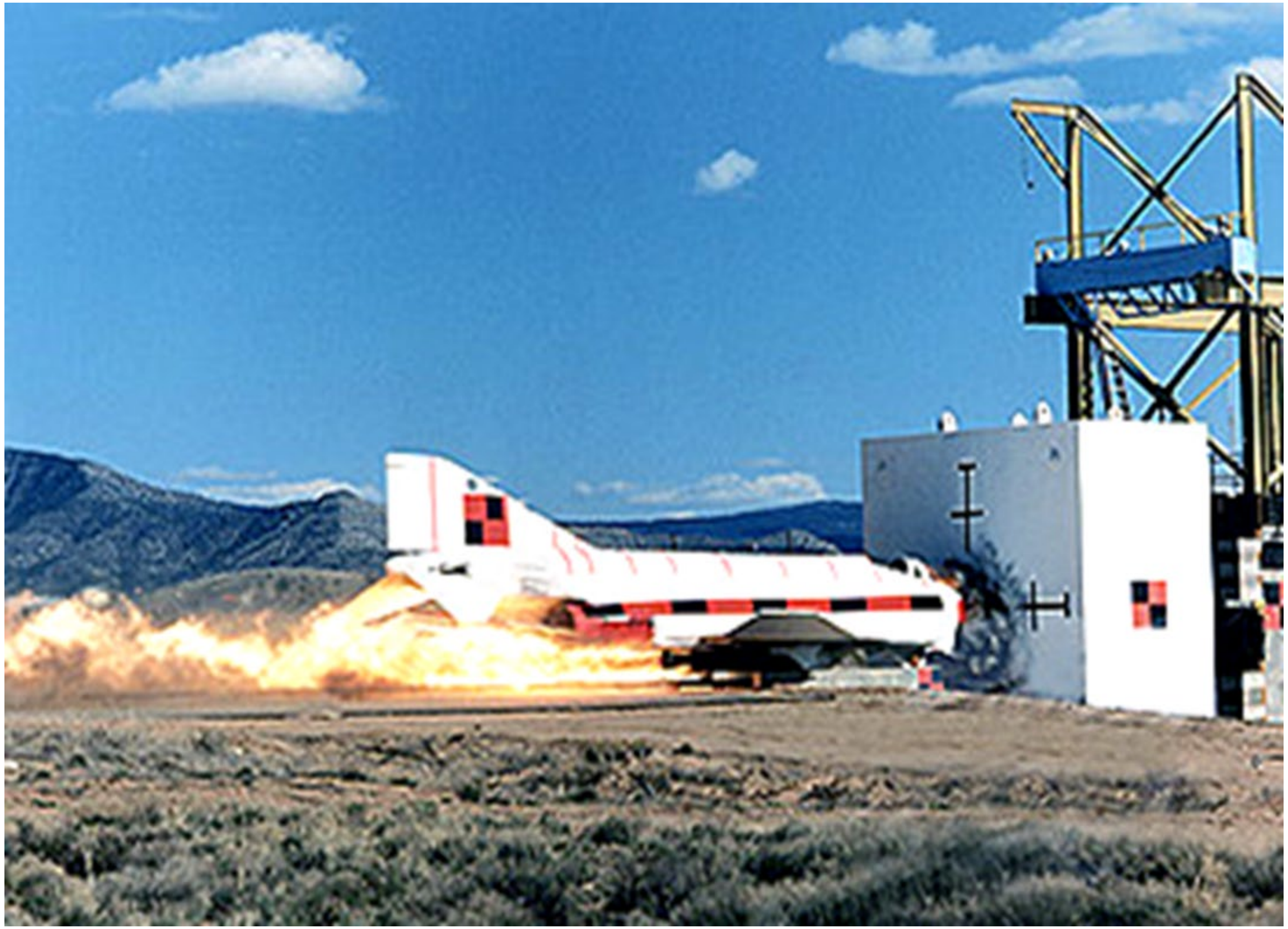


What Actually Matters: #3 Overload – Jamming Resistance

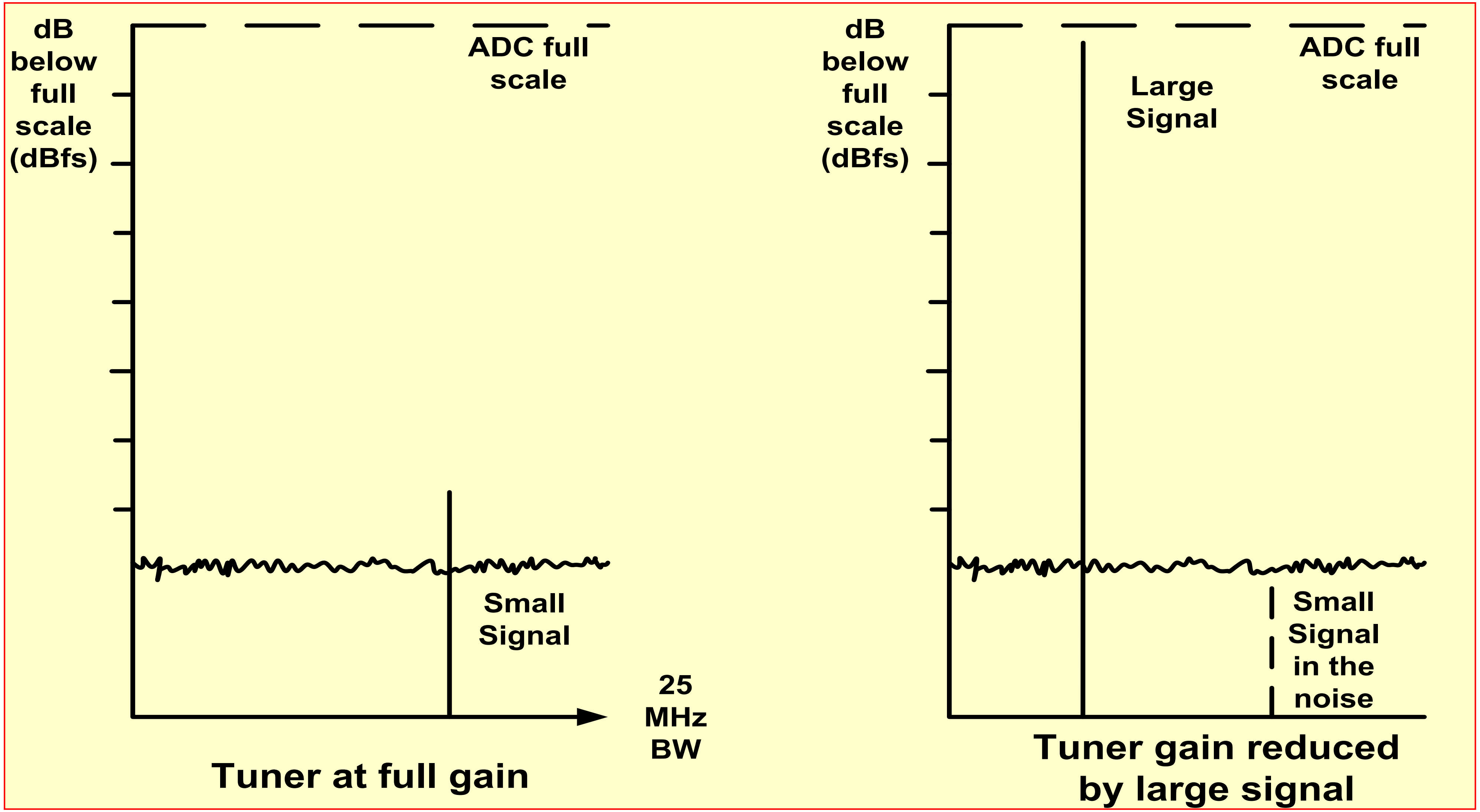
Rejecting Unwanted Signals

The radio environment is full of large unwanted signals.

Don’t Crash the A/D !!

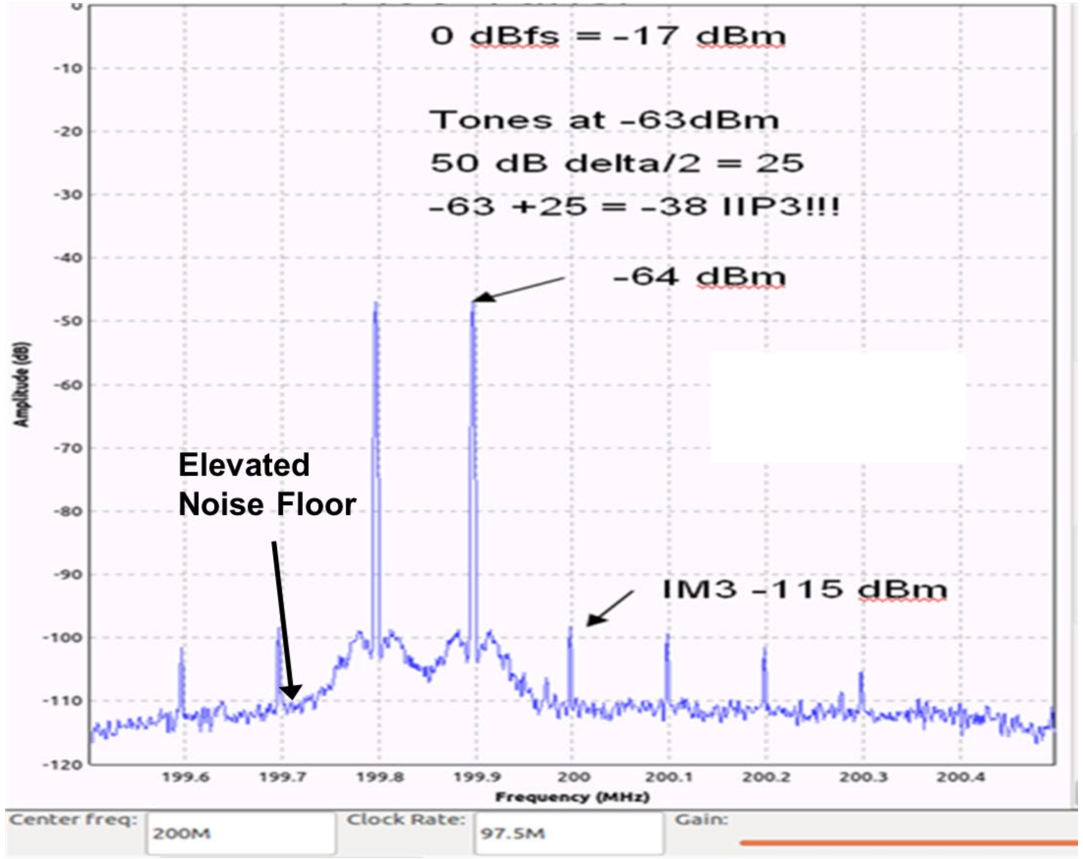


The Effect of Conventional Interfering Signal Management

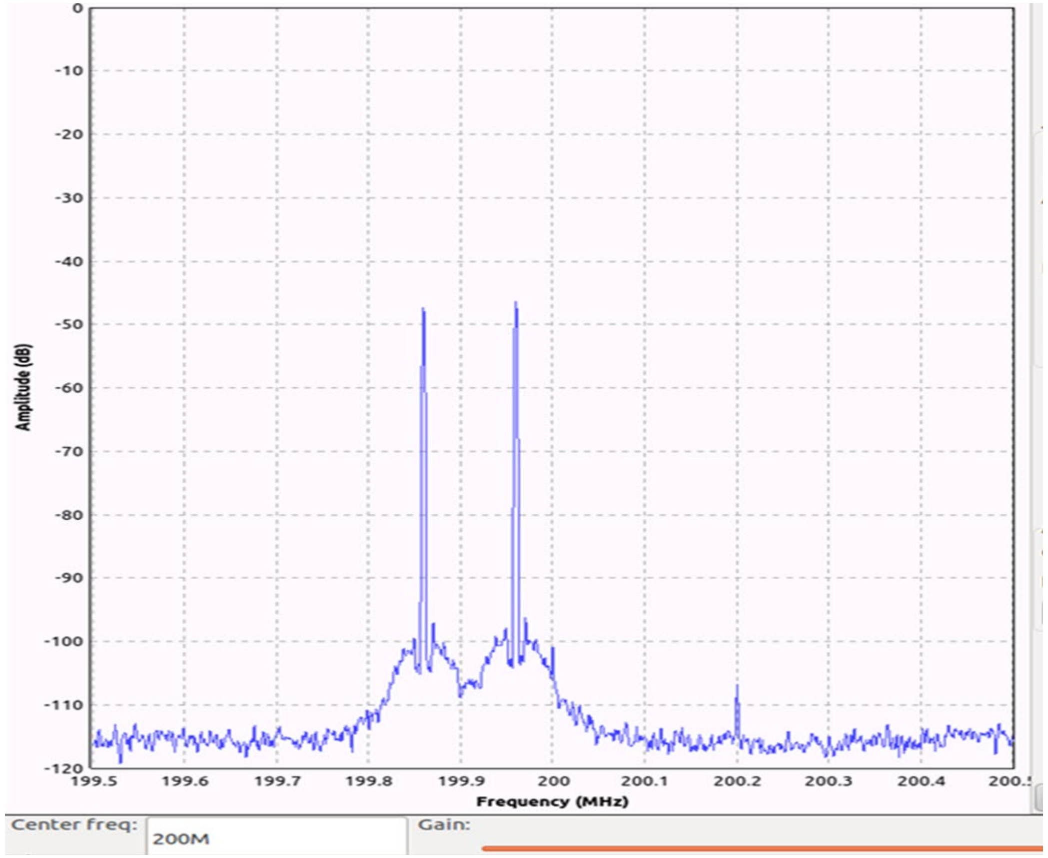


DRS ADC Integration Techniques and Performance

Poorly Handled ADC Spurs



Properly Mitigated Spurs



THANK **YOU**
FOR YOUR ATTENTION

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