Be Informed about Elevated HD Power

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Introduction

- **“HD is the best thing ever to happen to FM radio”**
- **“HD is the worst thing ever to happen to FM radio”**

HD Radio is neither of these but if you ask someone in the business you usually get one of the two responses above.

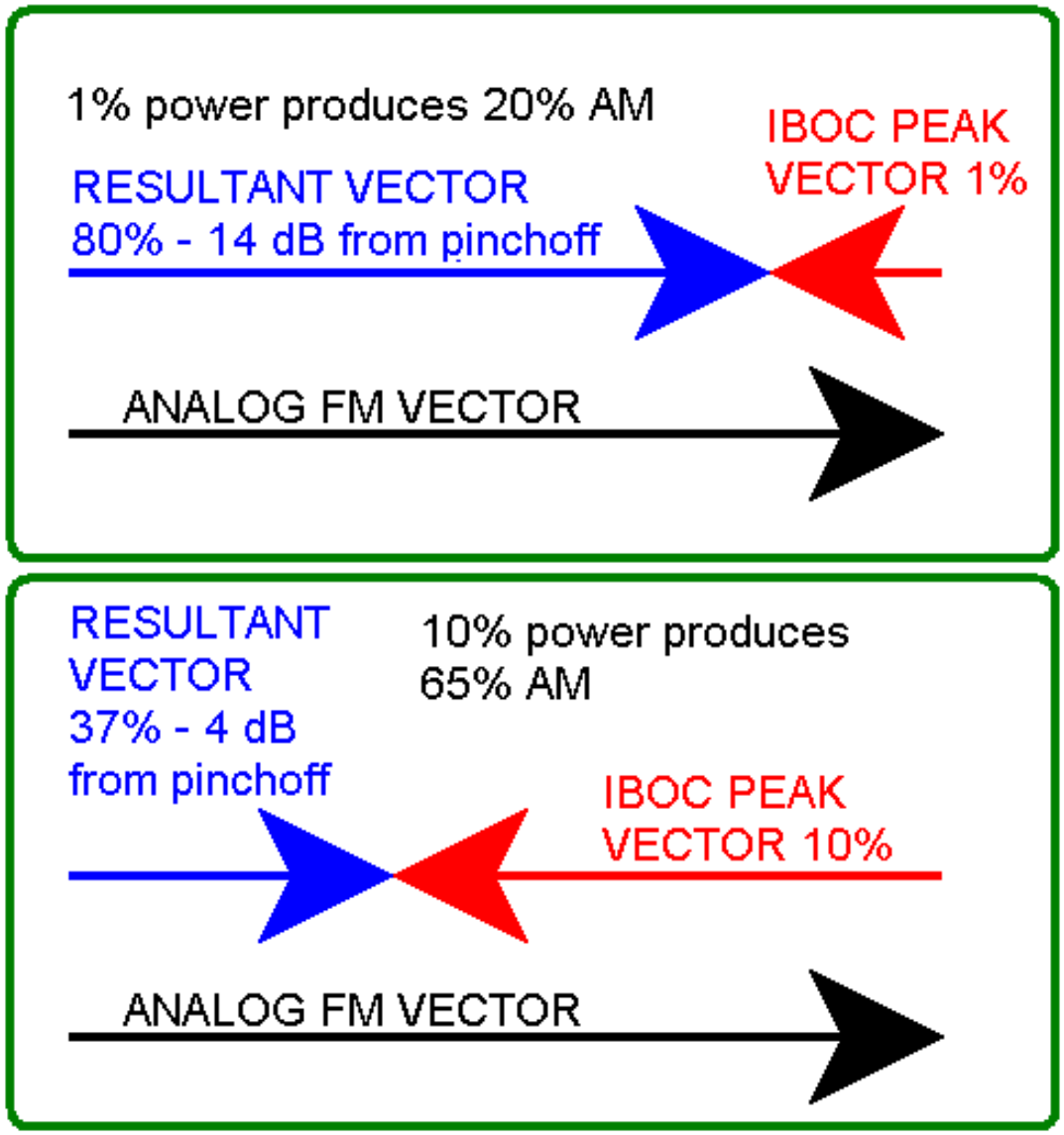
Topics for Discussion

- **Elevated HD Power Effects**
  - Improved HD coverage area
  - Increased adjacent channel interference
  - Increased self-interference
  - Increased multipath effects

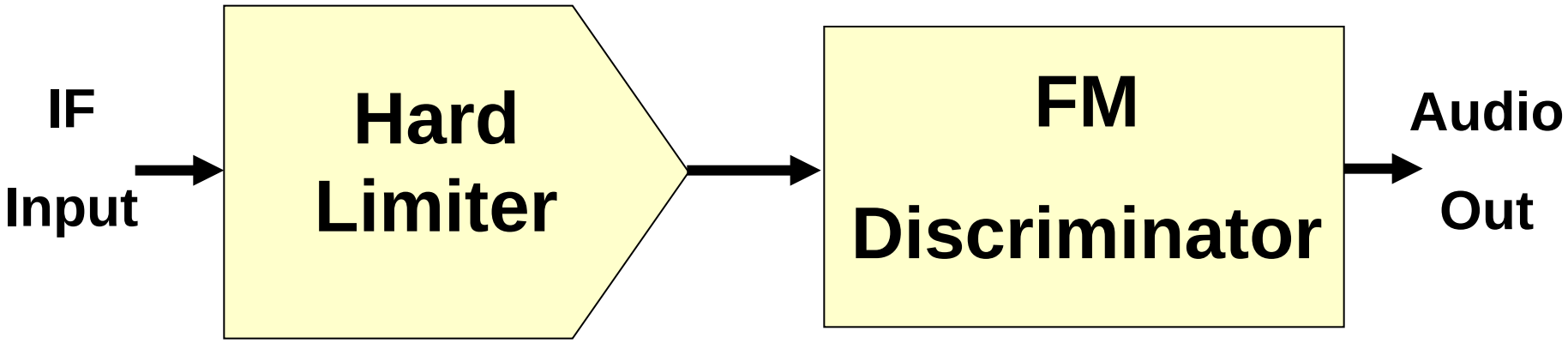
Envelope Modulation vs. Digital Power

Digital Power	Digital voltage (RMS, normalized)	Digital voltage (peak) (6 dB PAR)	Envelope Modulation (AM)	PEP (% of analog)
1%	0.1	0.2	20%	144%
4%	0.2	0.4	40%	196%
10%	0.316	0.632	63.2%	266%

Envelope Modulation and Pinchoff

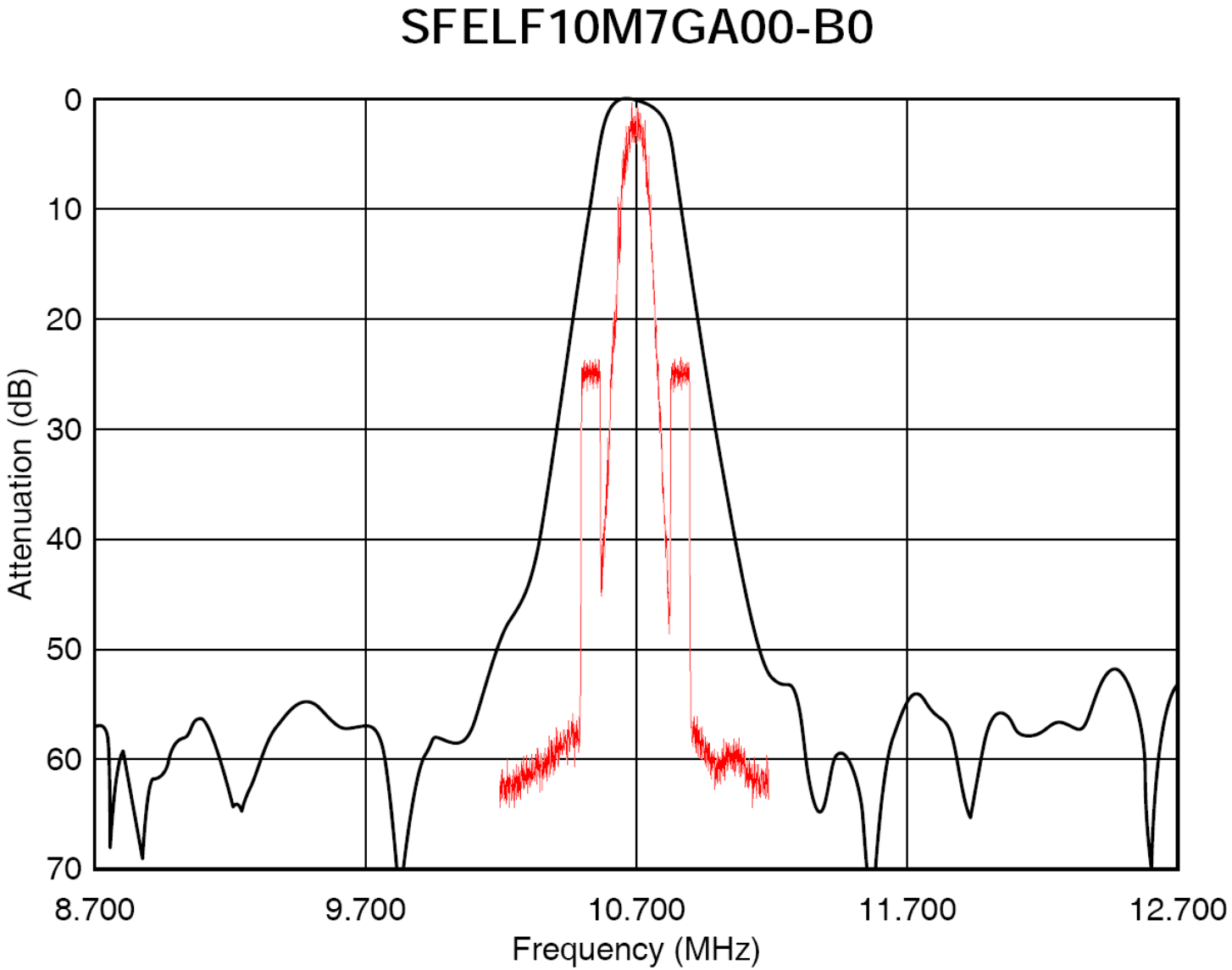


Analog FM Receiver

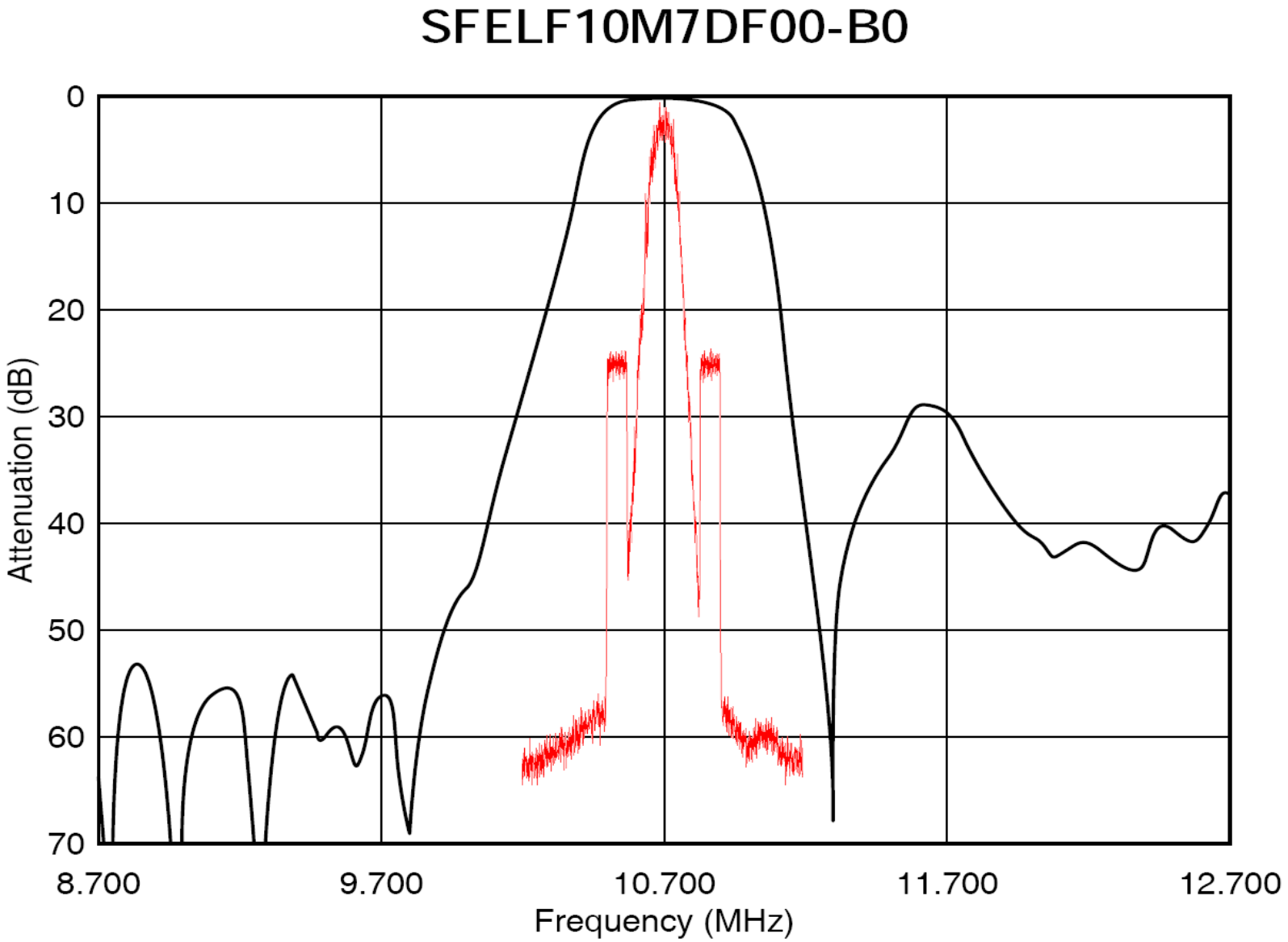


- Hard limiter – its gain is the reciprocal of its input amplitude
- Envelope pinchoff (zero envelope) creates noise bursts
- Minimizing positive AM is important for transmitters – but minimizing negative AM is important for receivers

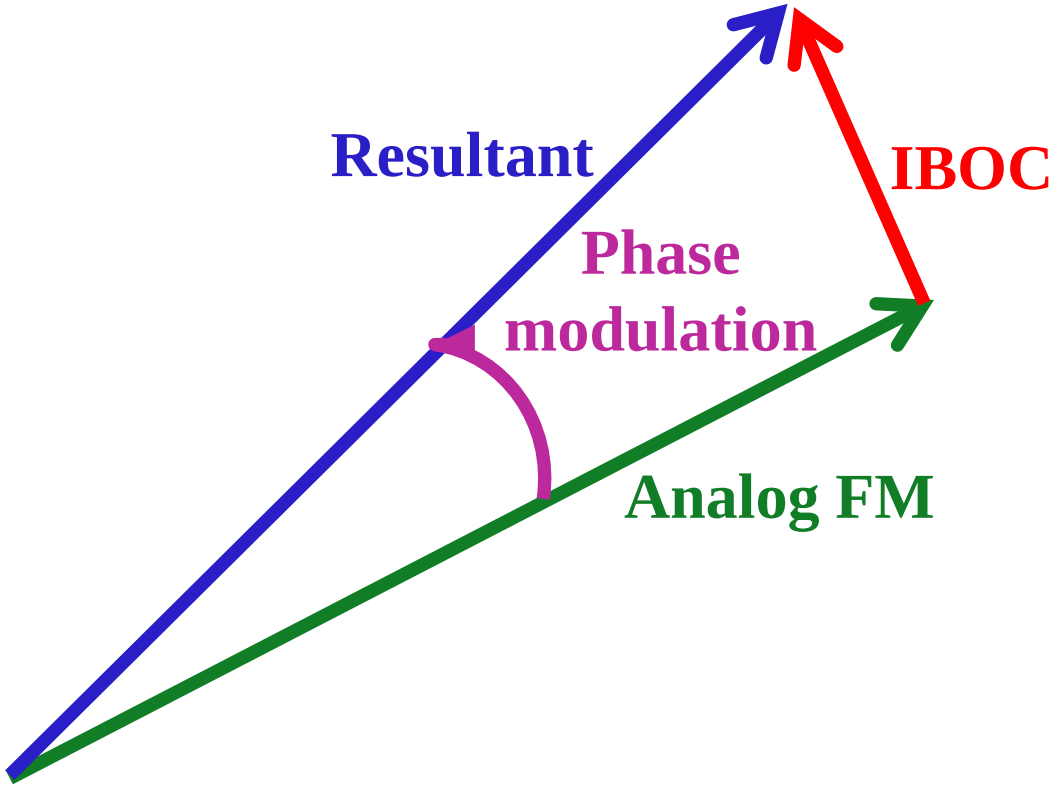
IBOC in Narrow Murata IF Filter



IBOC and Wide Murata IF Filter

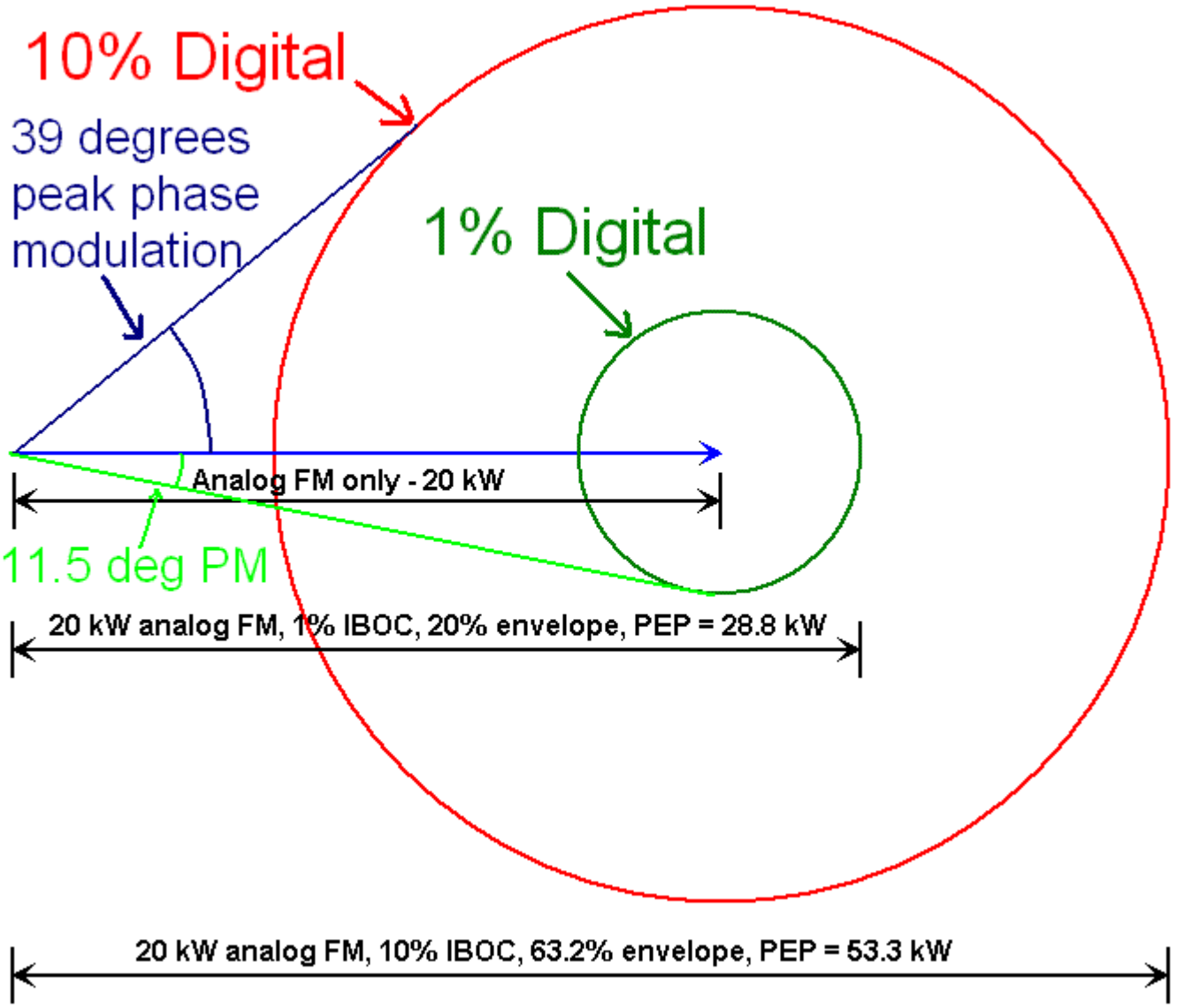


Phase Modulation Introduced by IBOC

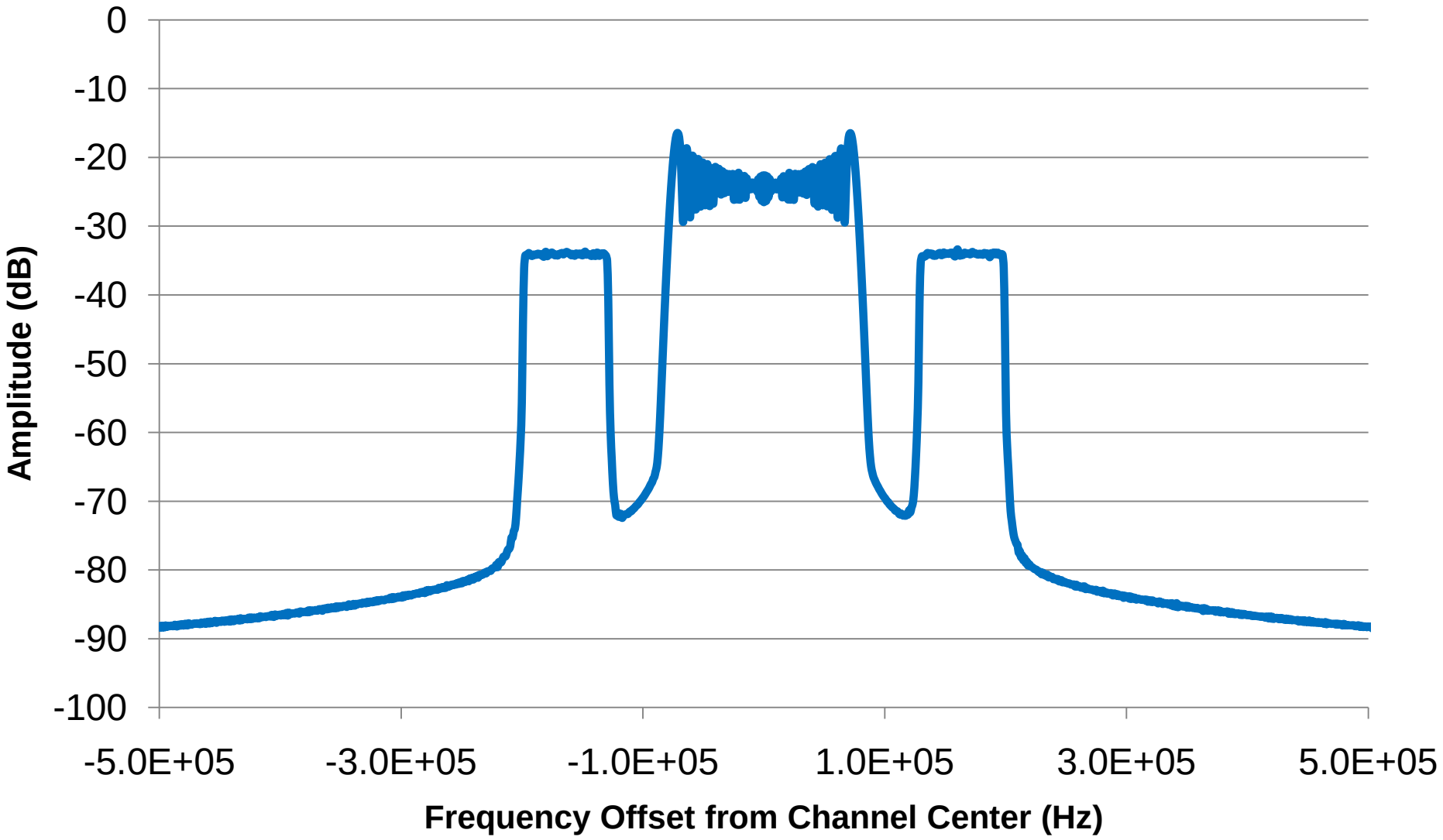


Demodulated FM is proportional to the derivative of the phase modulation

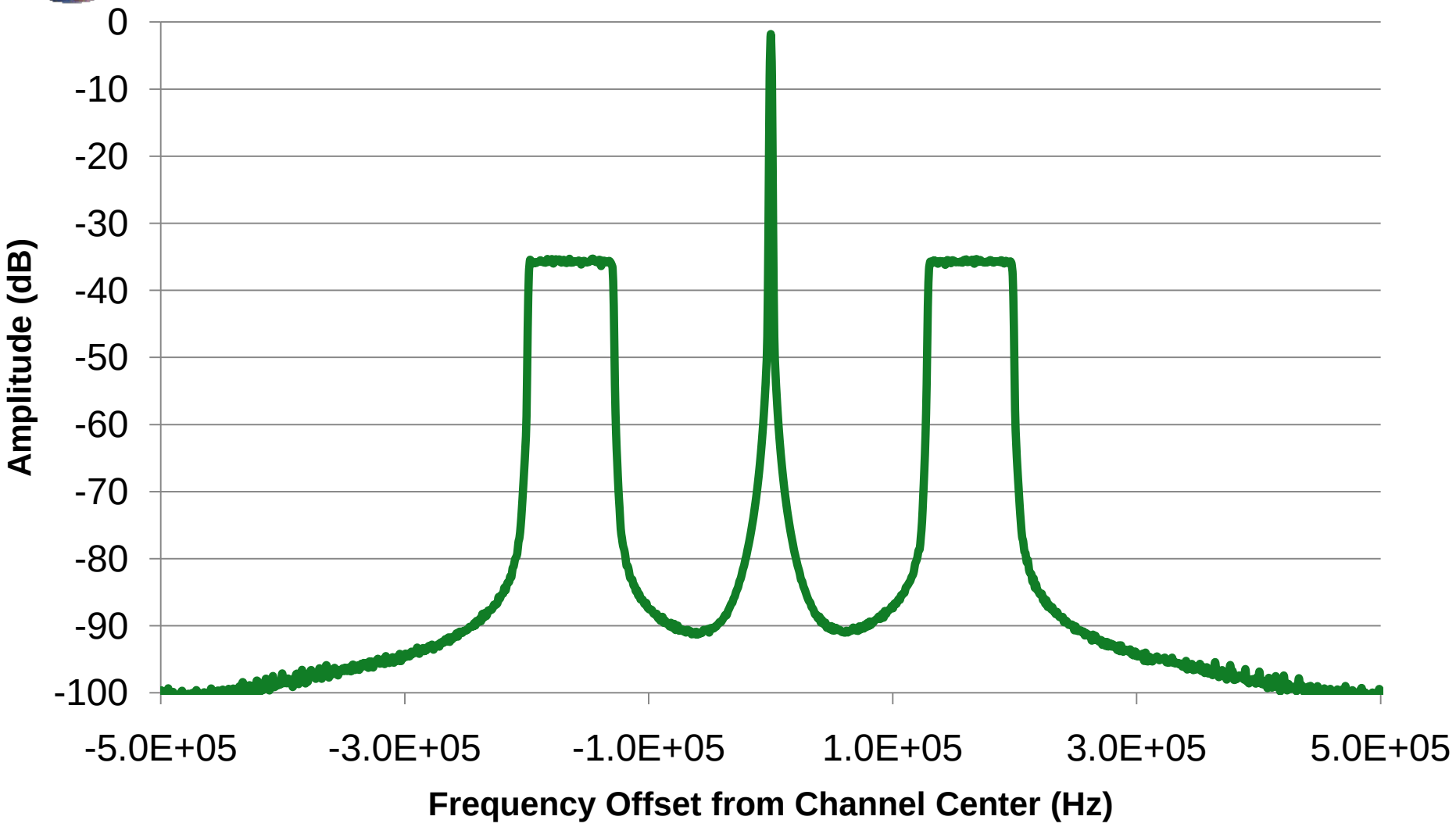
Phase Modulation Introduced by IBOC



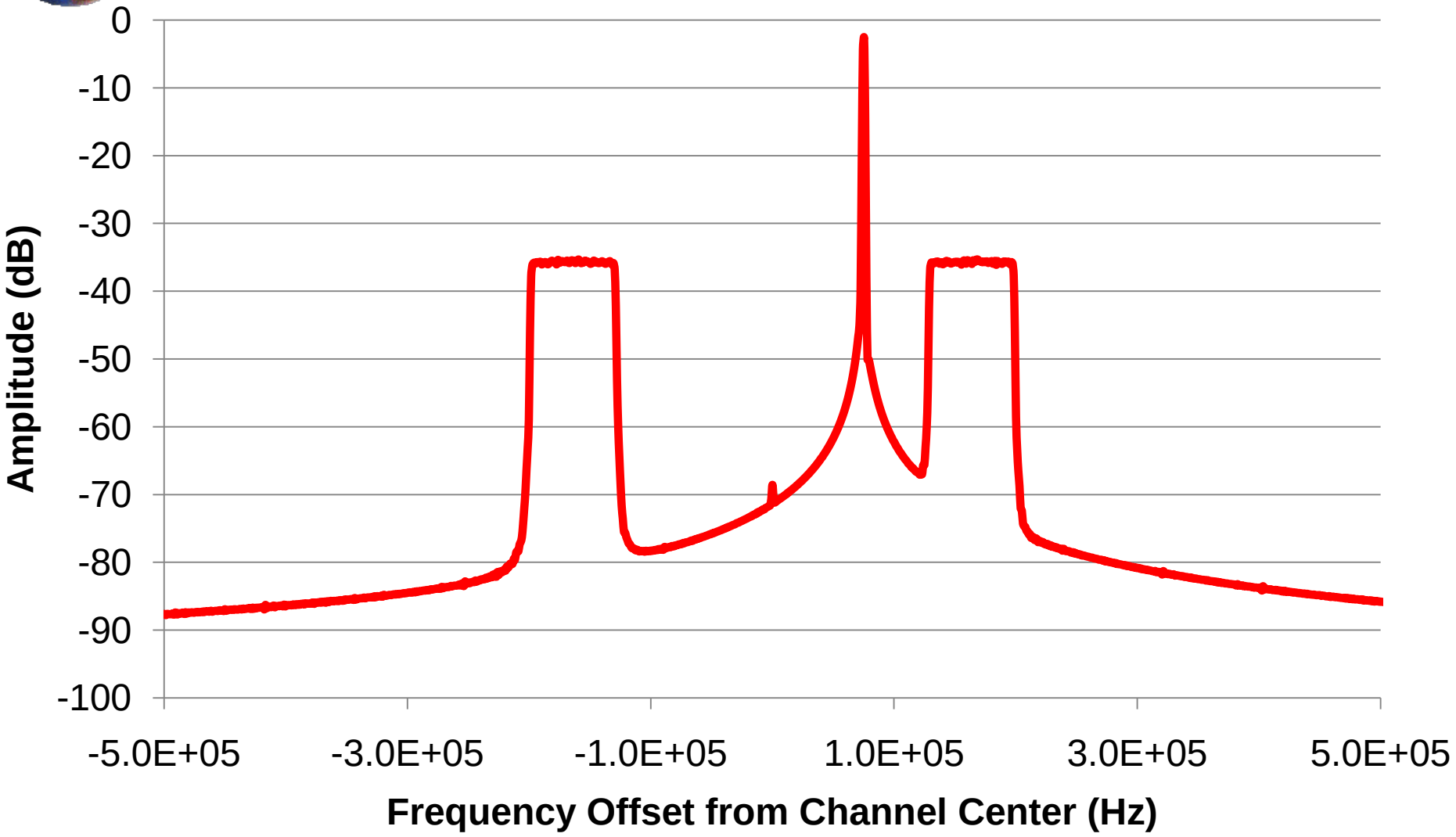
Hybrid Spectrum with 1 kHz Mono Tone



Hybrid Spectrum with No FM Deviation



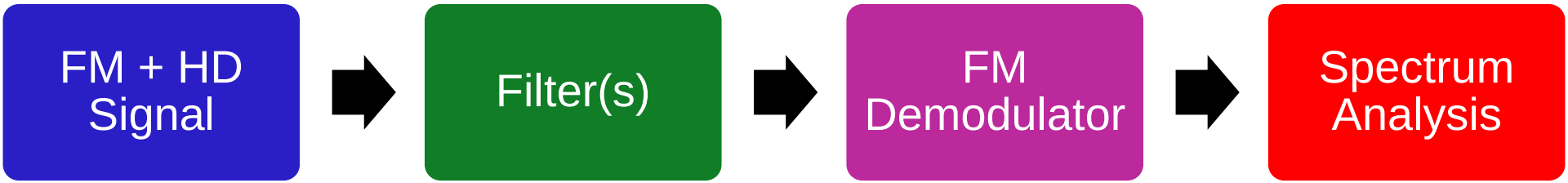
Hybrid Spectrum with 75 kHz “DC” Deviation



Simulation of Analog Reception of HD+FM

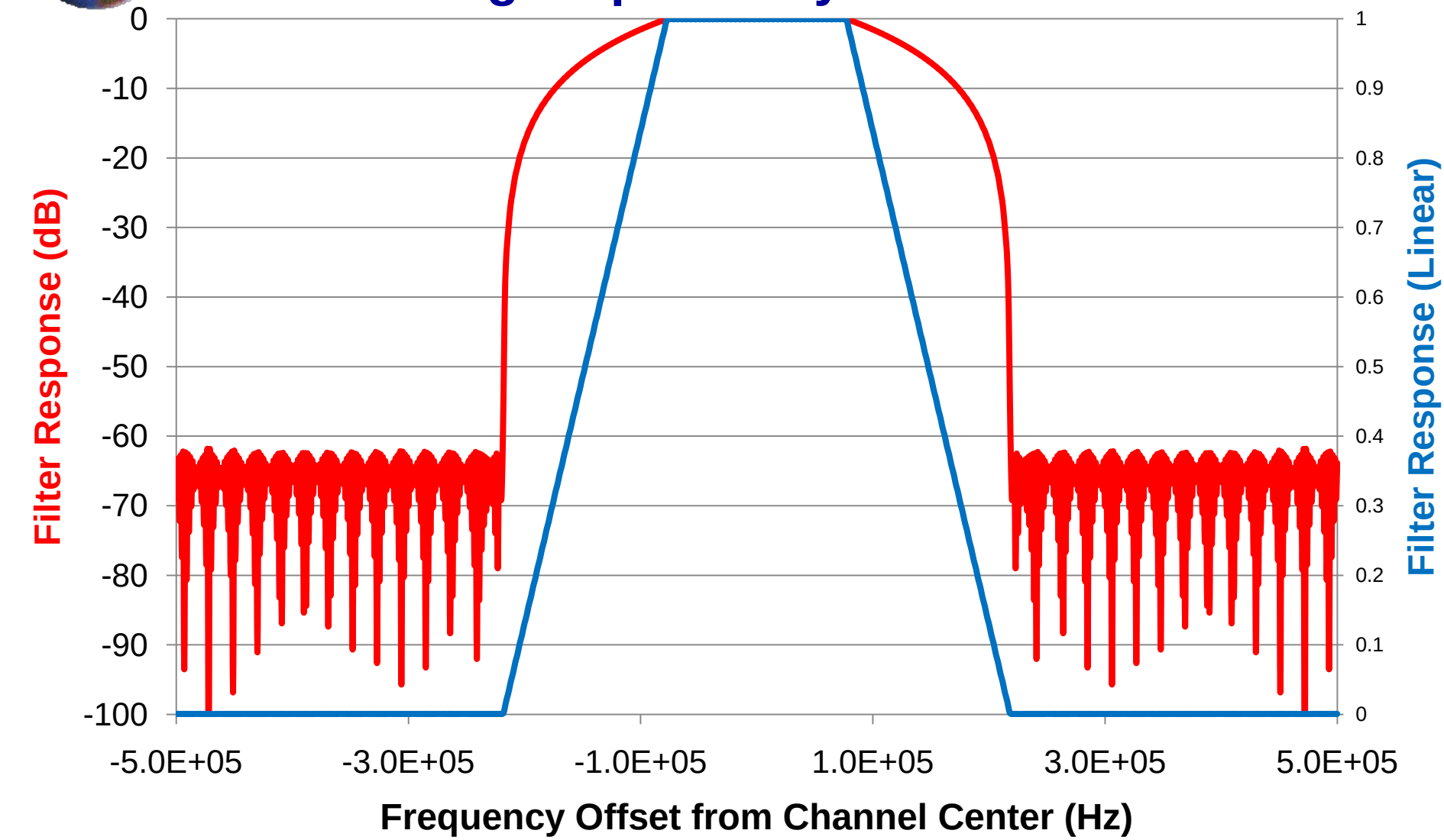
(May simulate bandpass filtering and/or multipath)

Perfect limiter & FM detector



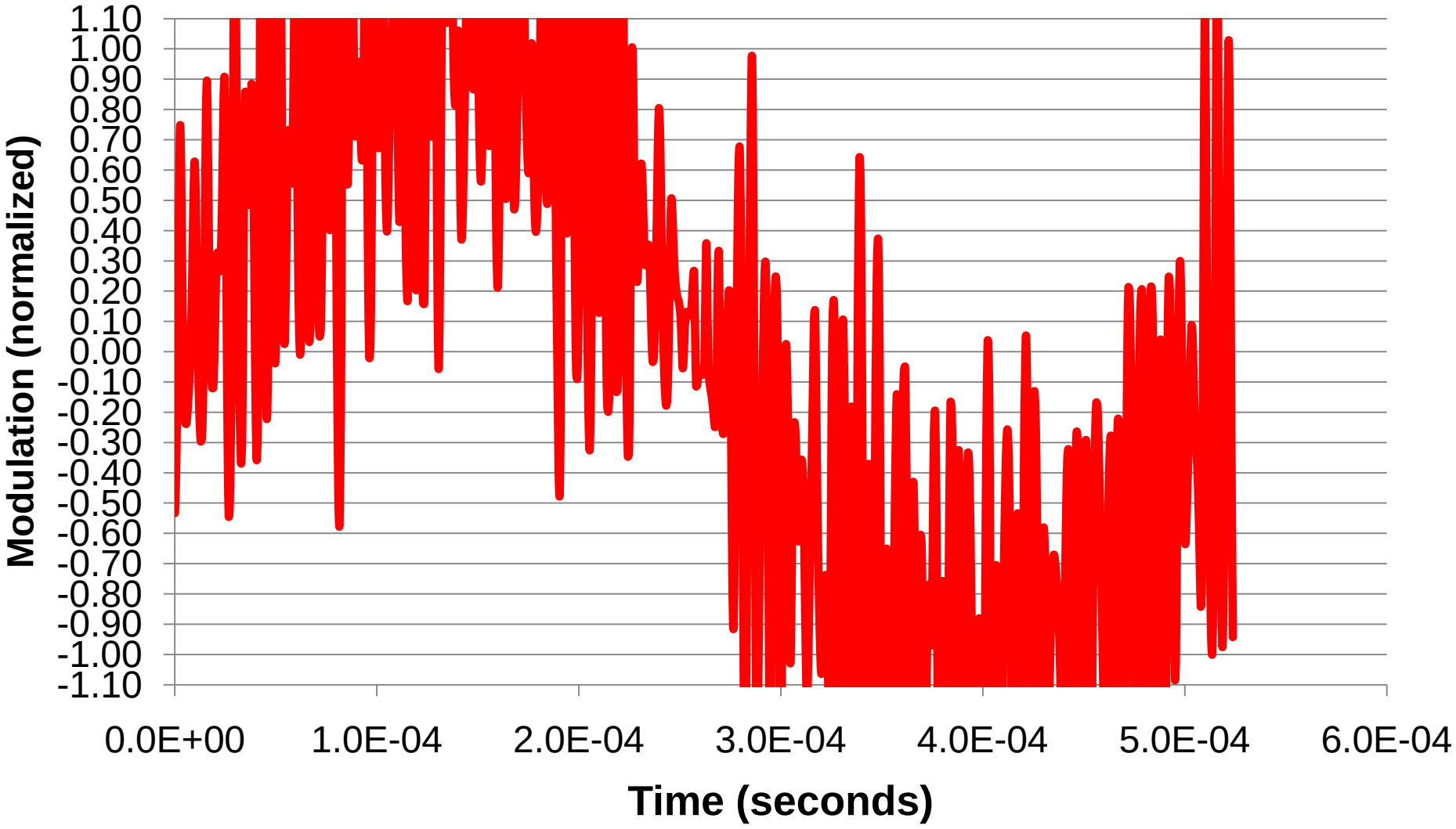
$$FM(t) = Q(t) \times \frac{dI}{dt} - I(t) \times \frac{dQ}{dt}$$

Simulation of Narrow Murata Bandpass Filter
Reduces digital power by 6.7 dB



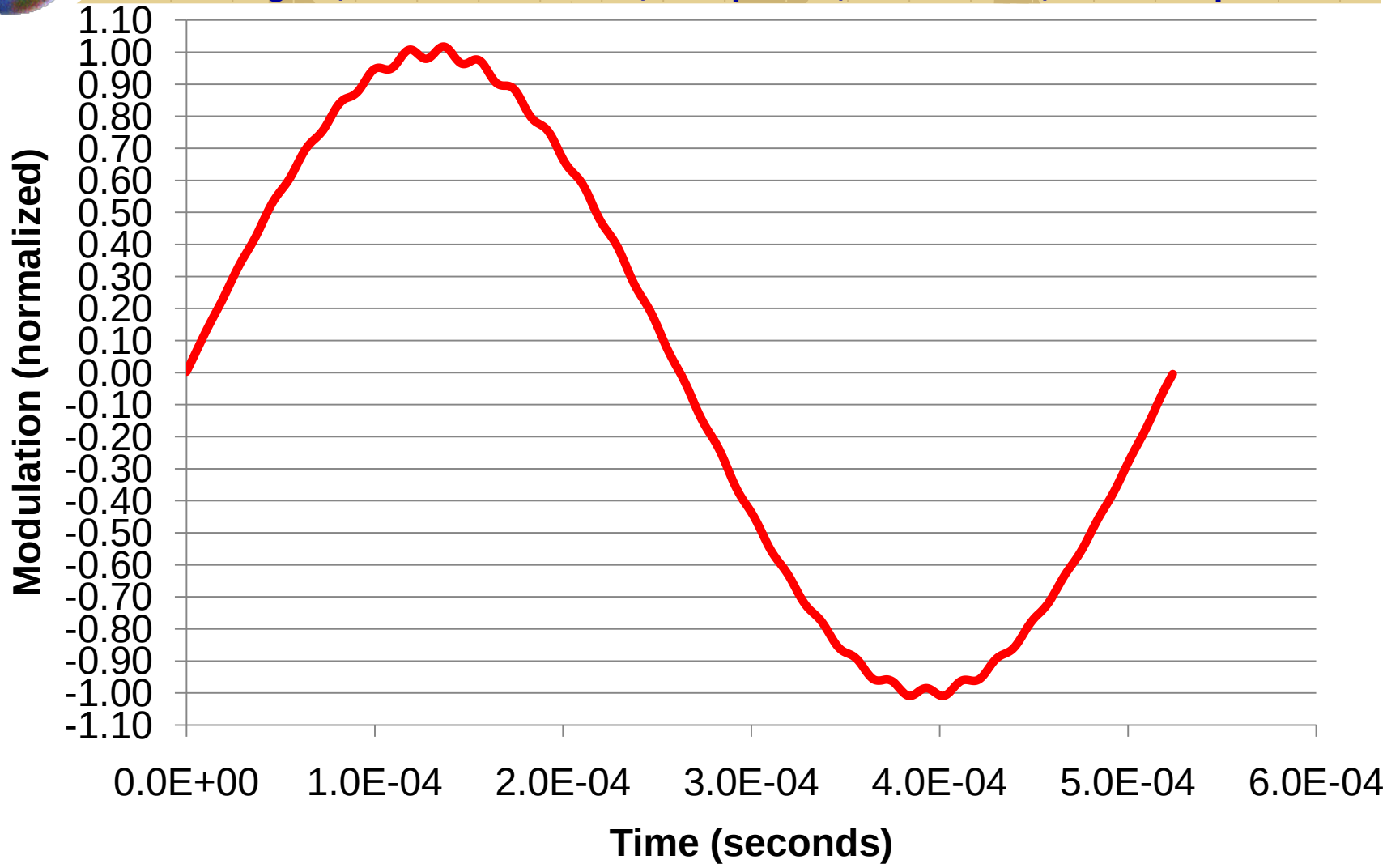
Demodulated FM – Time Domain

10% digital, 1.9 kHz mono FM, no de-emphasis, no filtering



Demodulated FM – Time Domain

10% digital, 1.9 kHz mono FM, sharp filter, 53 kHz LPF, no de-emphasis



Demodulated FM – Time Domain

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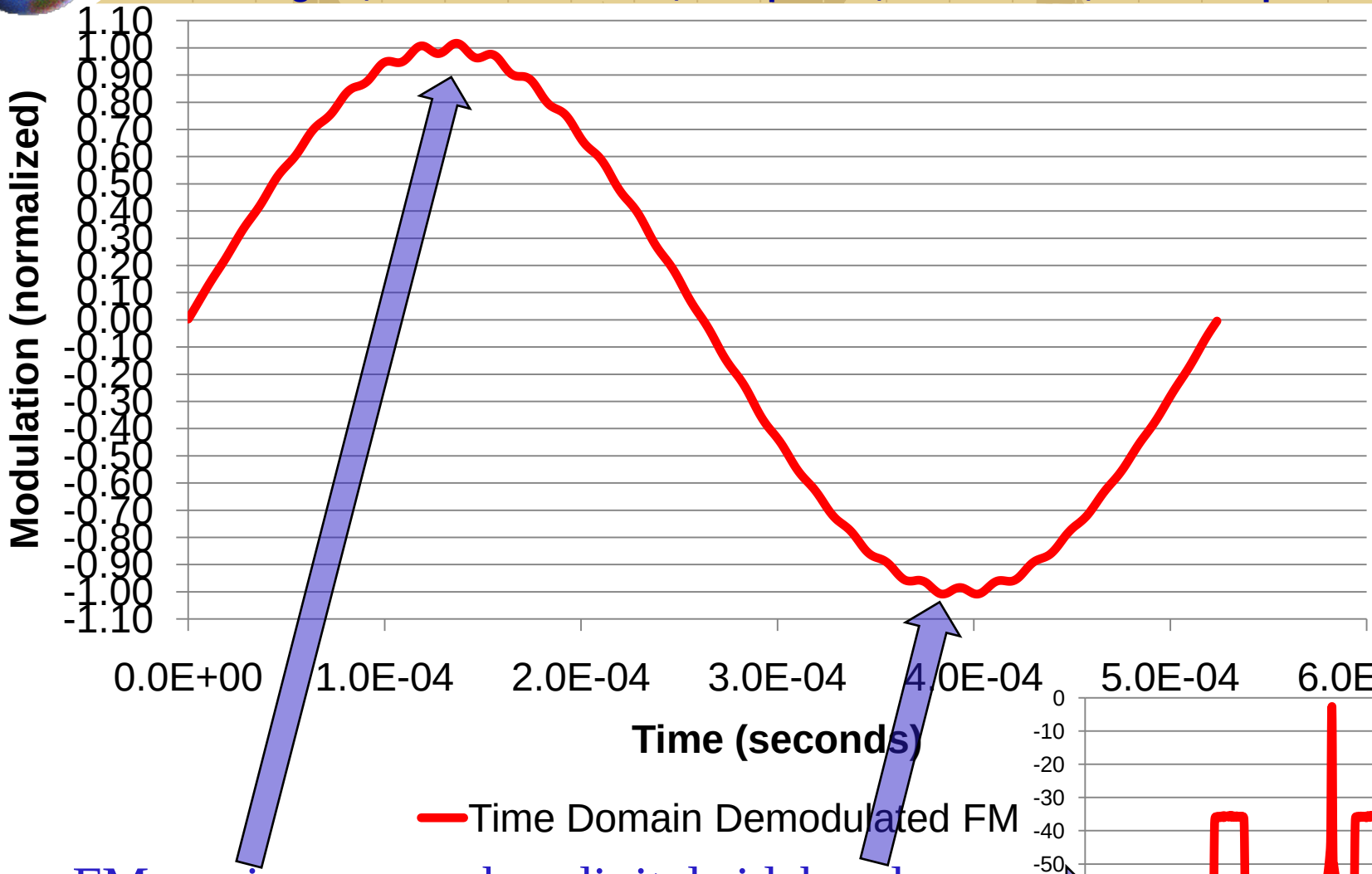
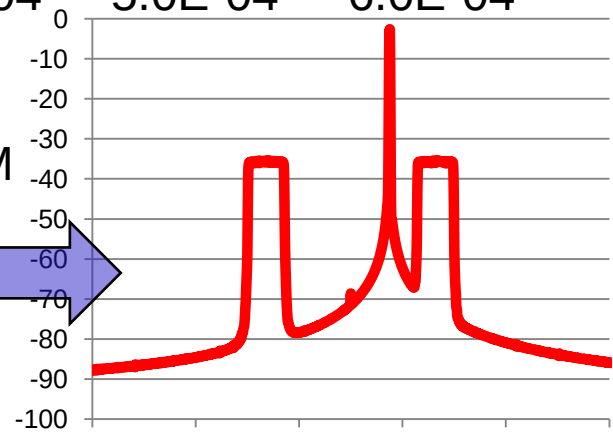
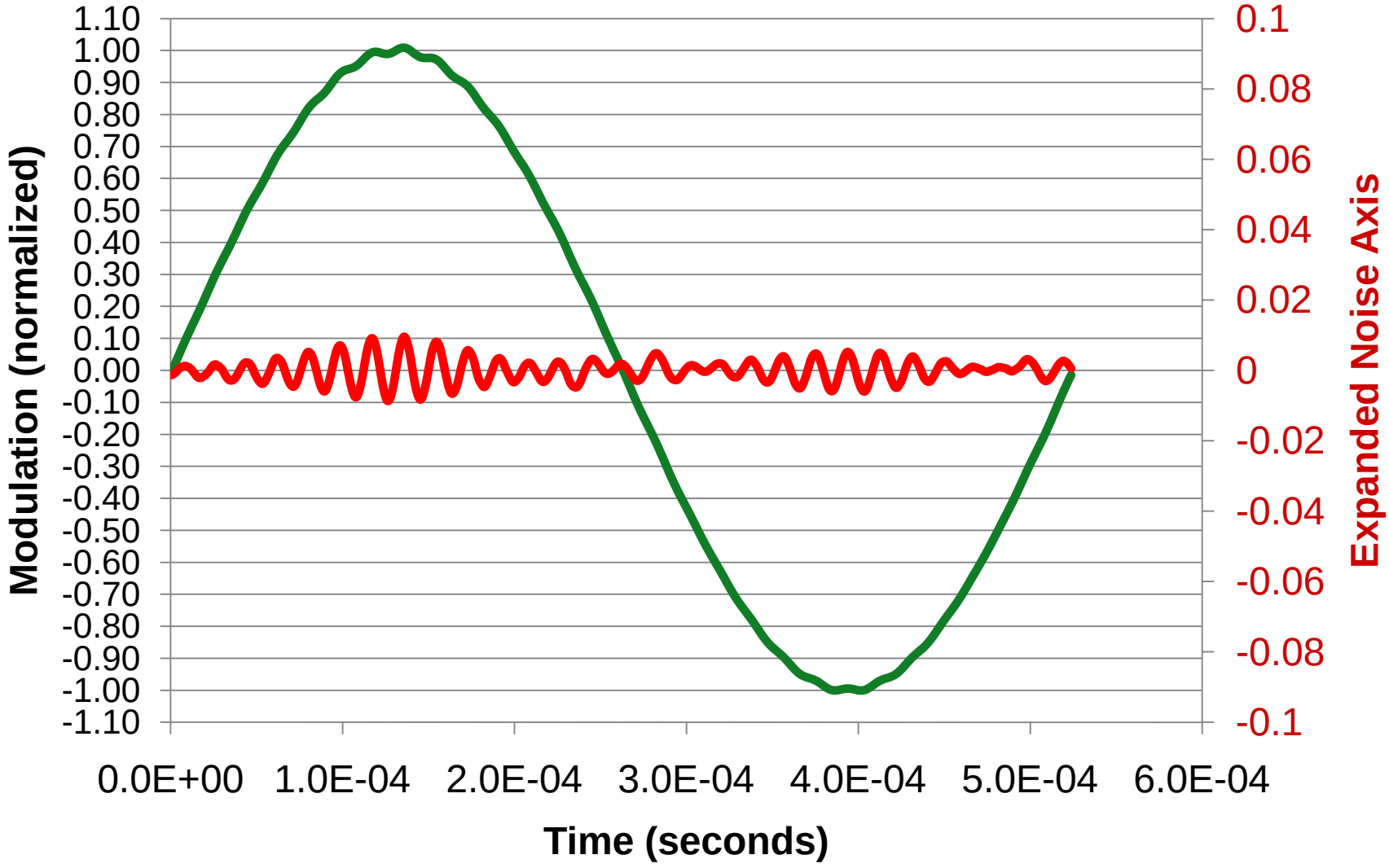


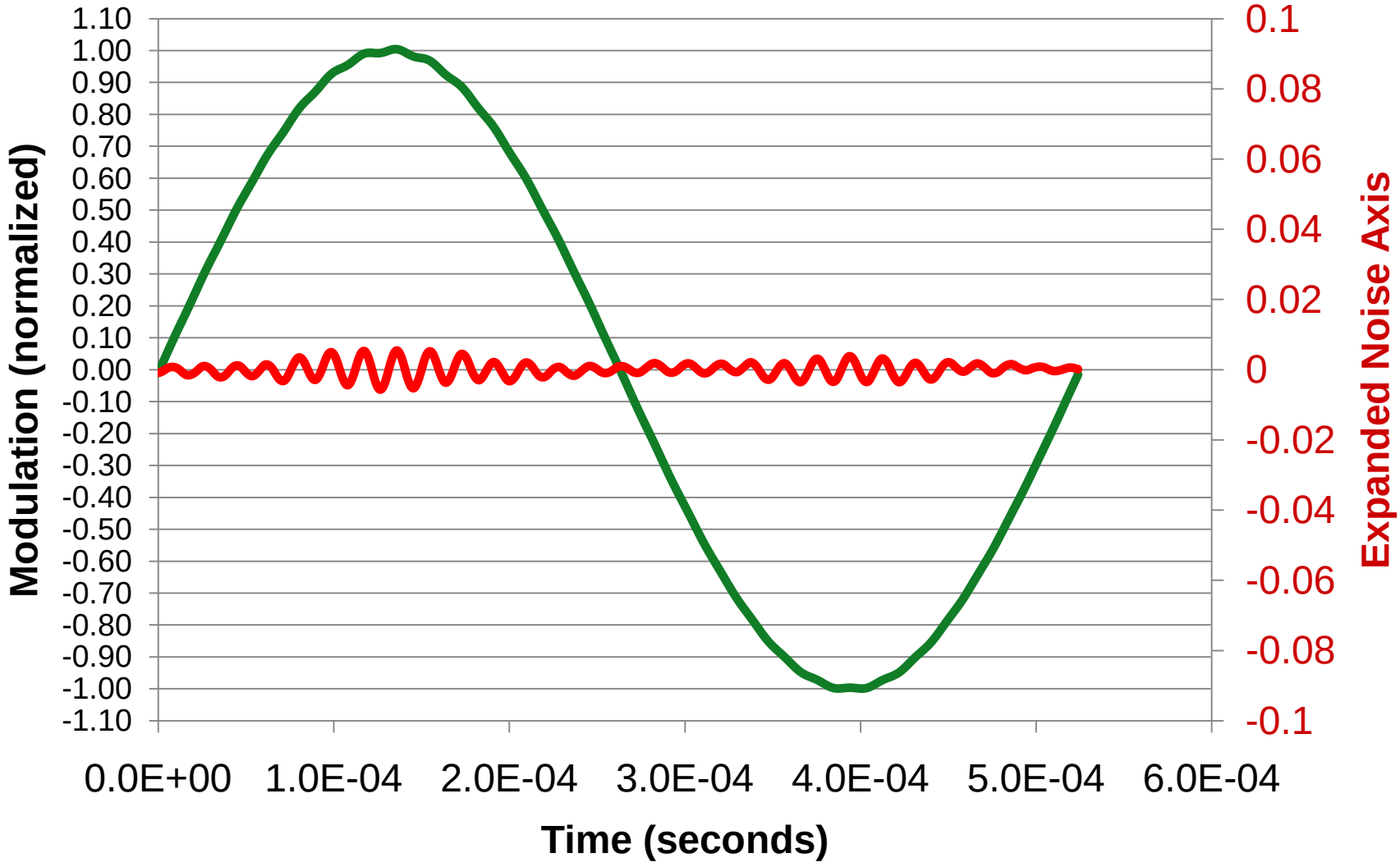


FM carrier approaches digital sidebands, producing lower beat notes

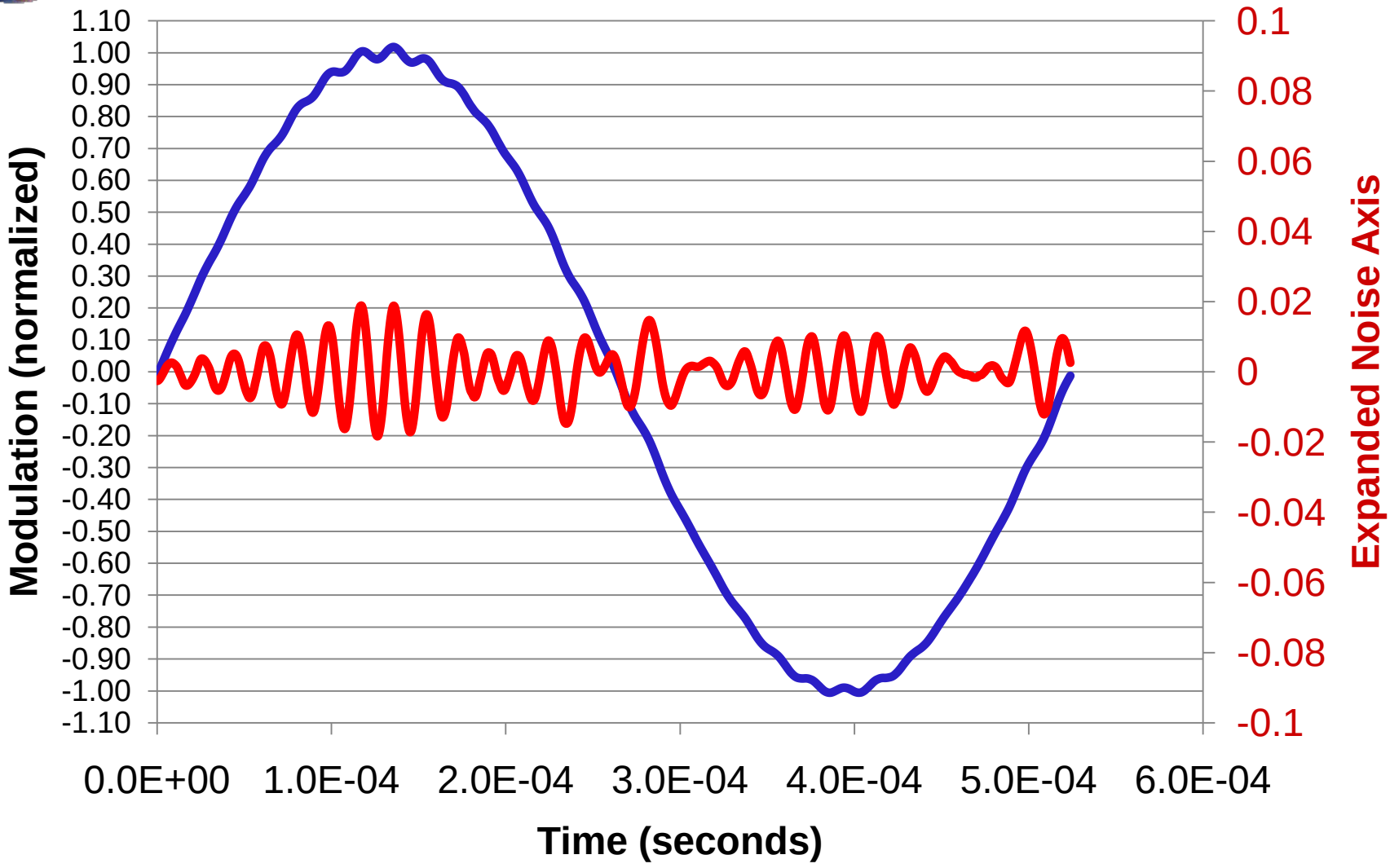
1% Digital, 53 kHz LPF, no IF filtering



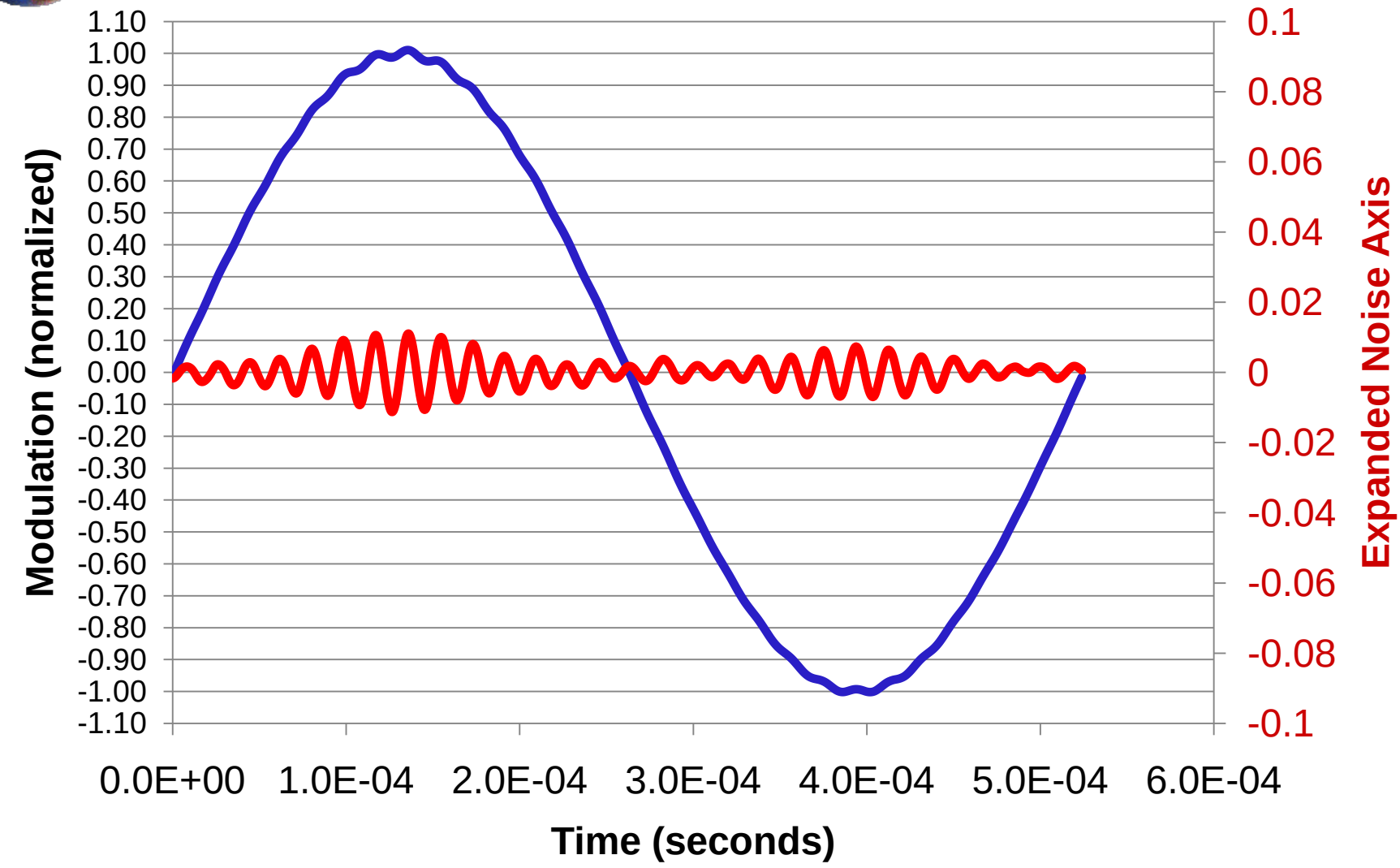
1% Digital, 53 kHz LPF, sharp IF filtering



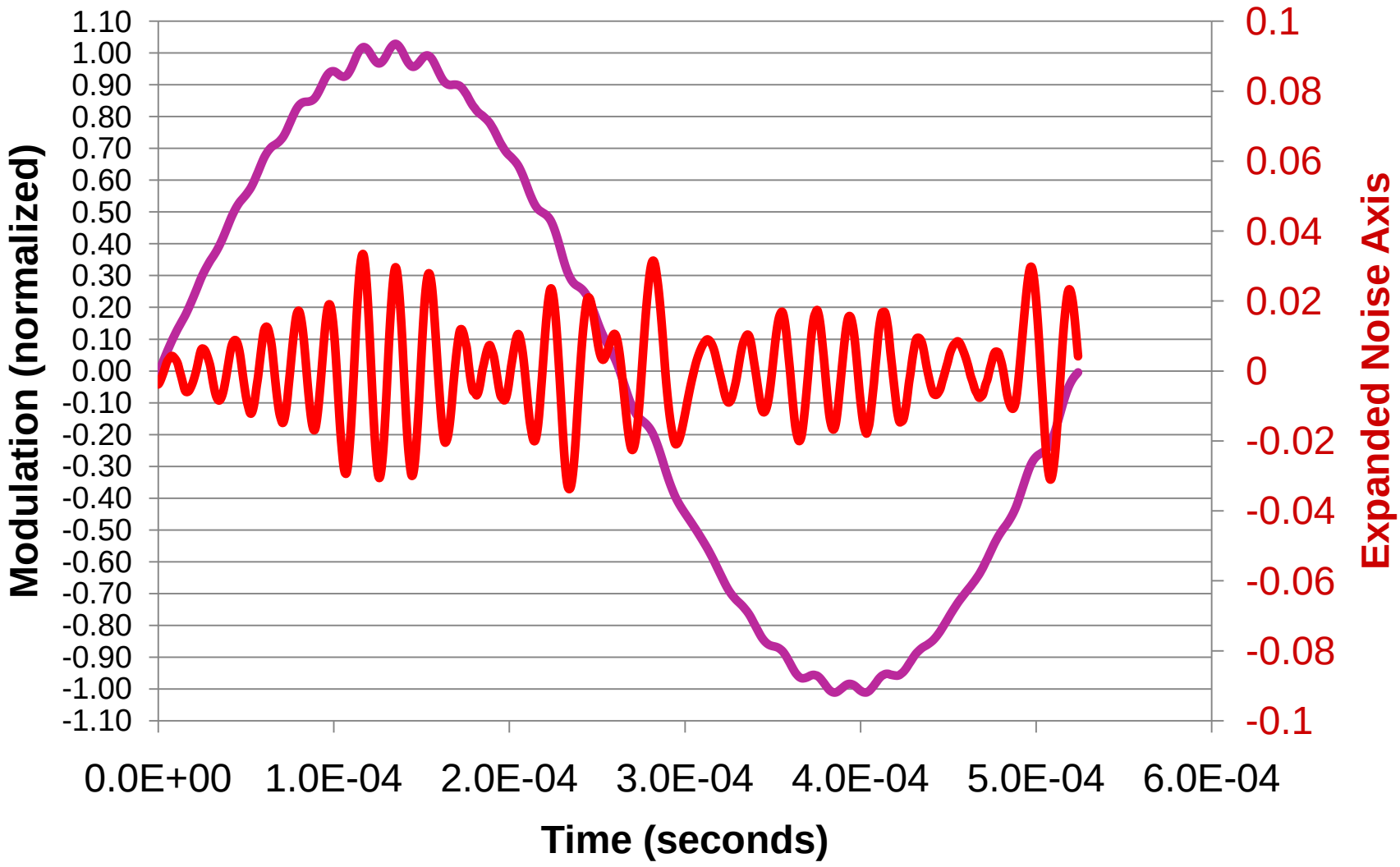
4% Digital, 53 kHz LPF, no IF filtering



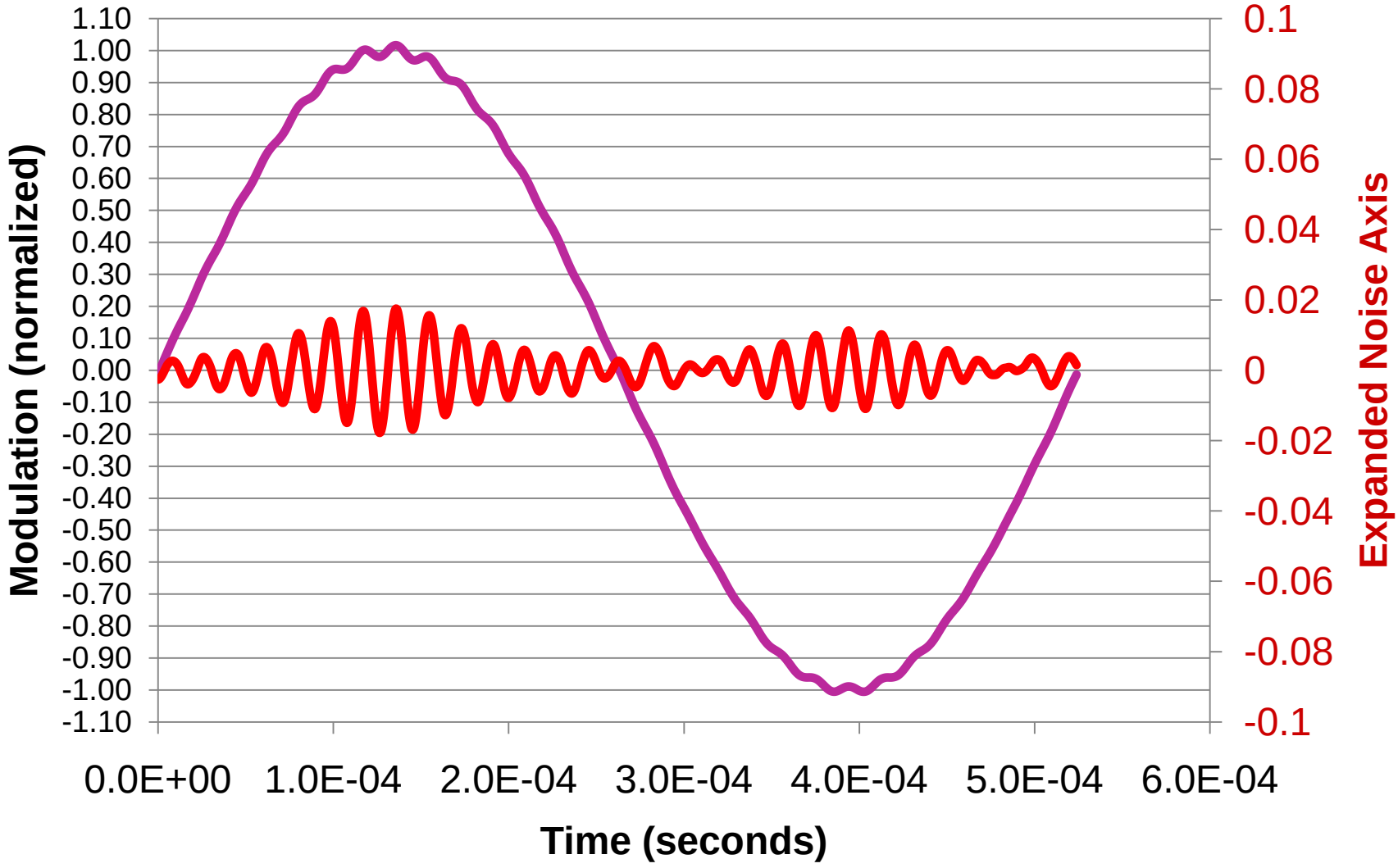
4% Digital, 53 kHz LPF, sharp IF filtering



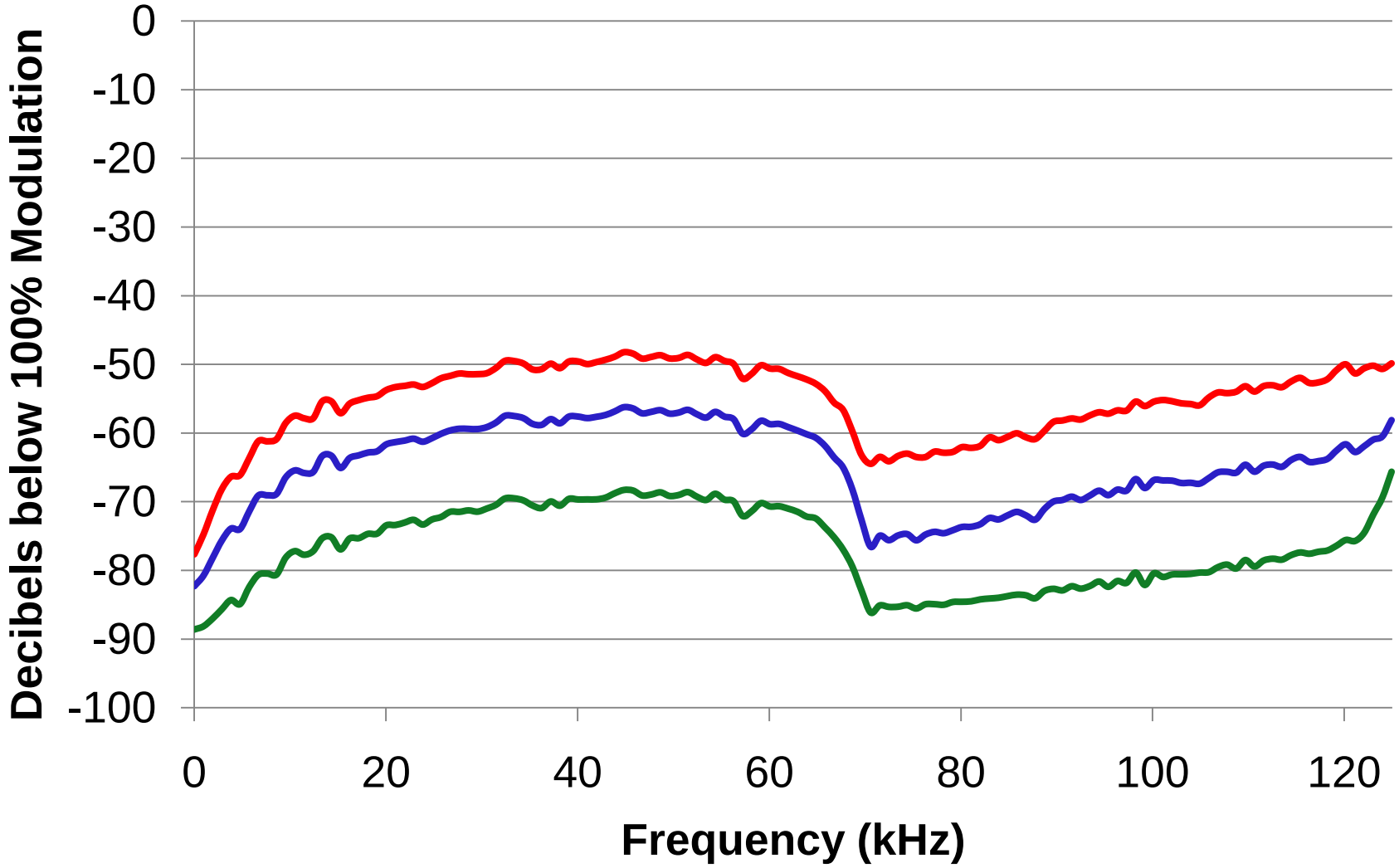
10% Digital, 53 kHz LPF, no IF filtering



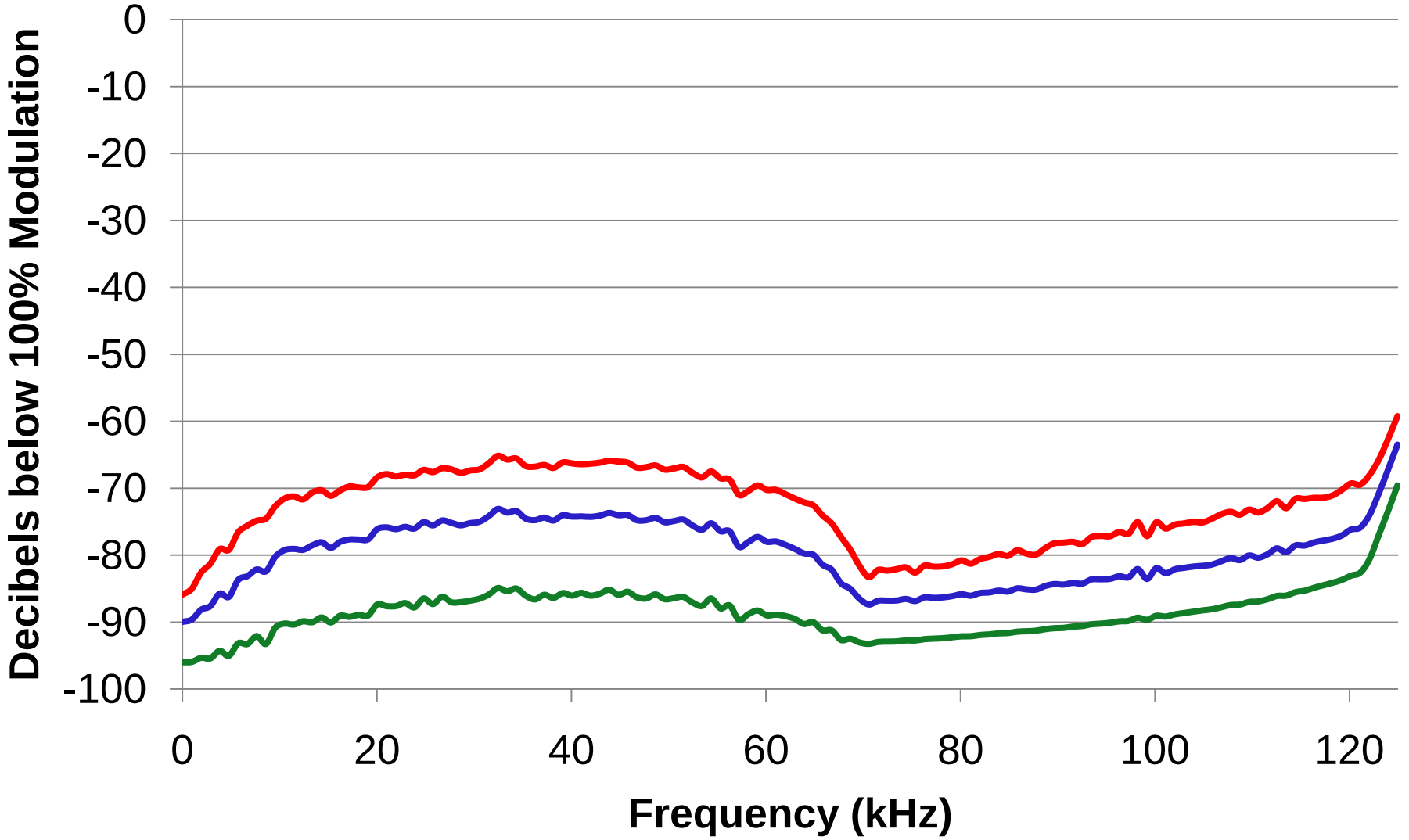
10% Digital, 53 kHz LPF, sharp IF filtering



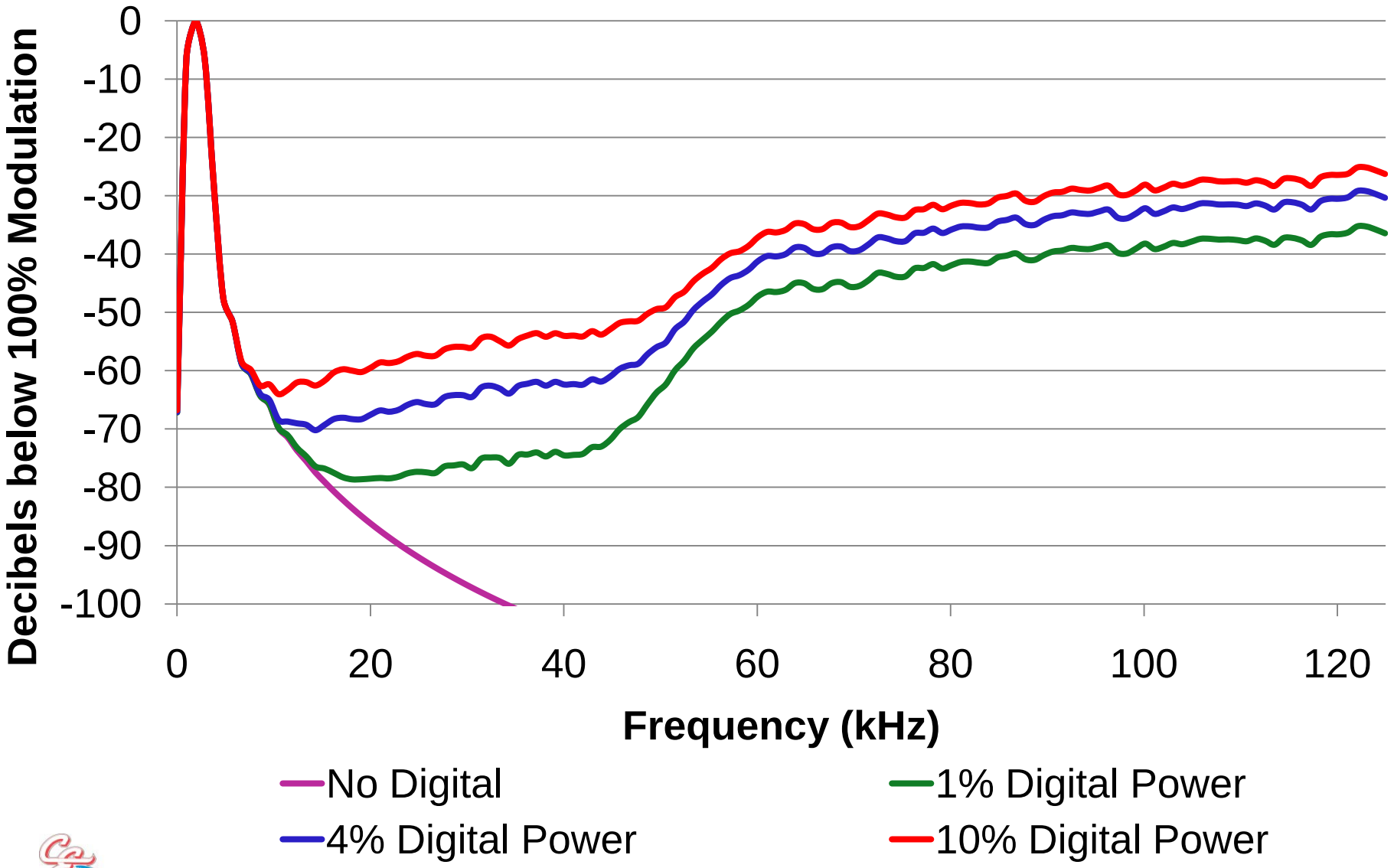
Demodulated FM Composite – No FM Deviation



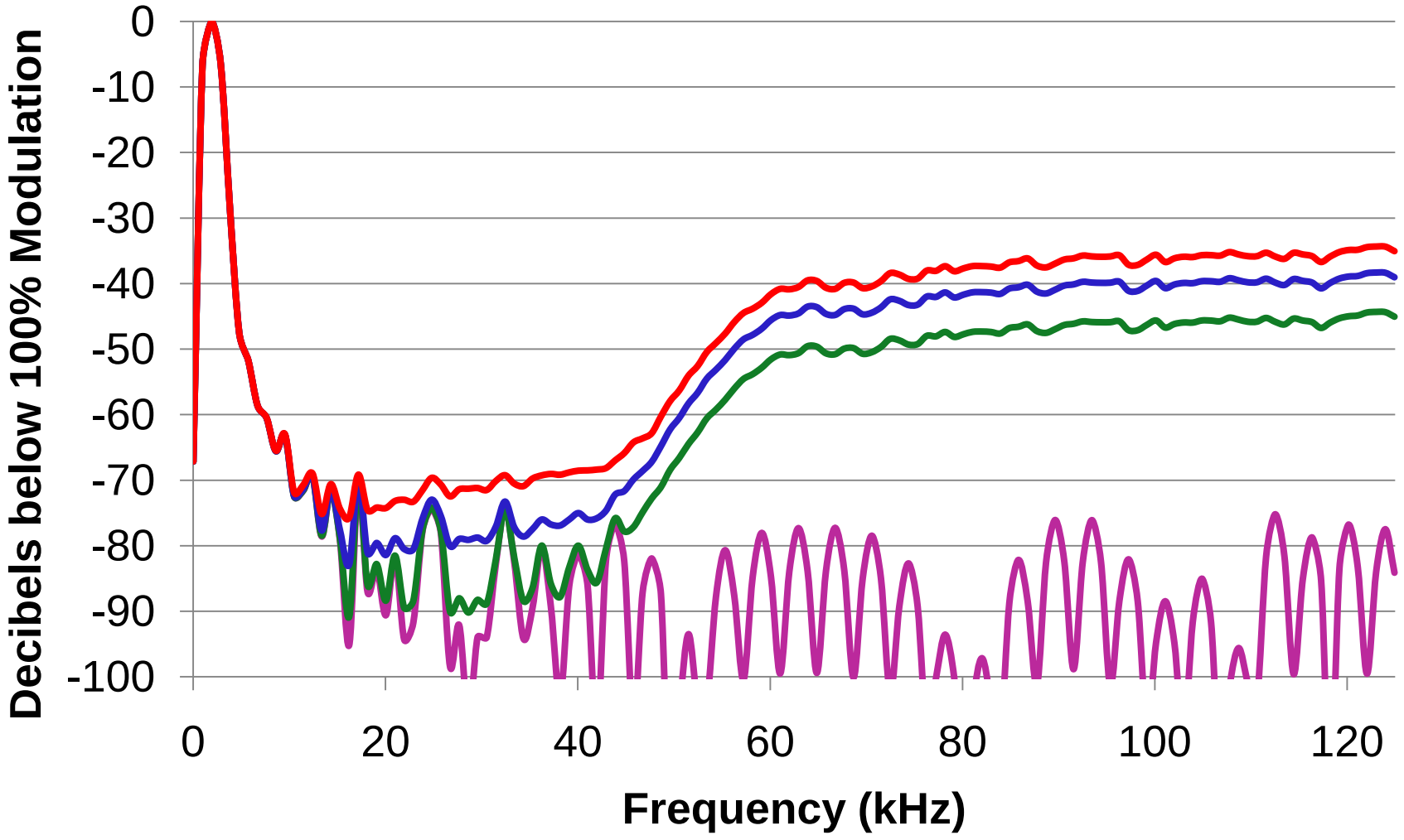
Sharp Filtered FM Composite – no FM



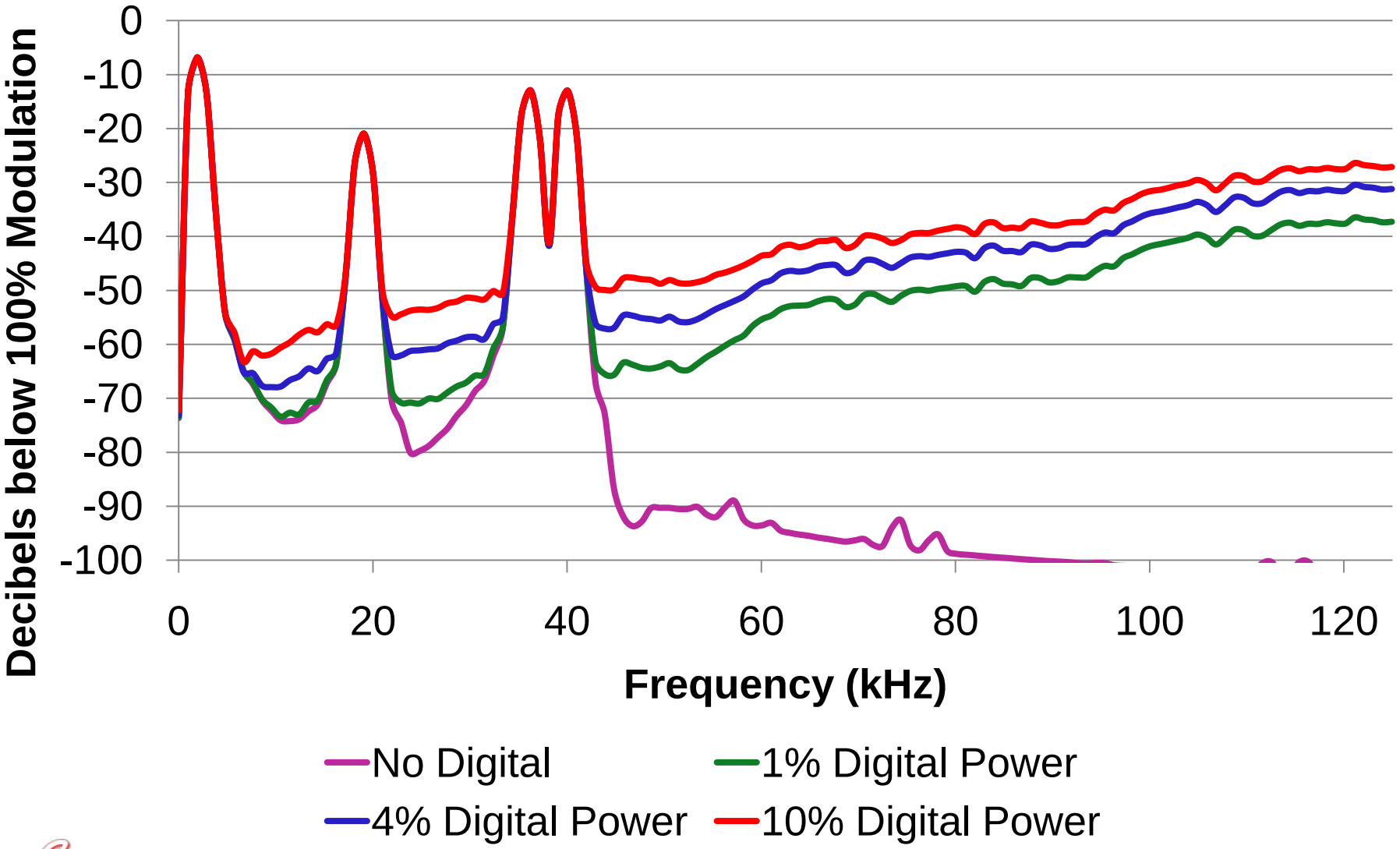
Demodulated FM Composite – 1.9 kHz Mono



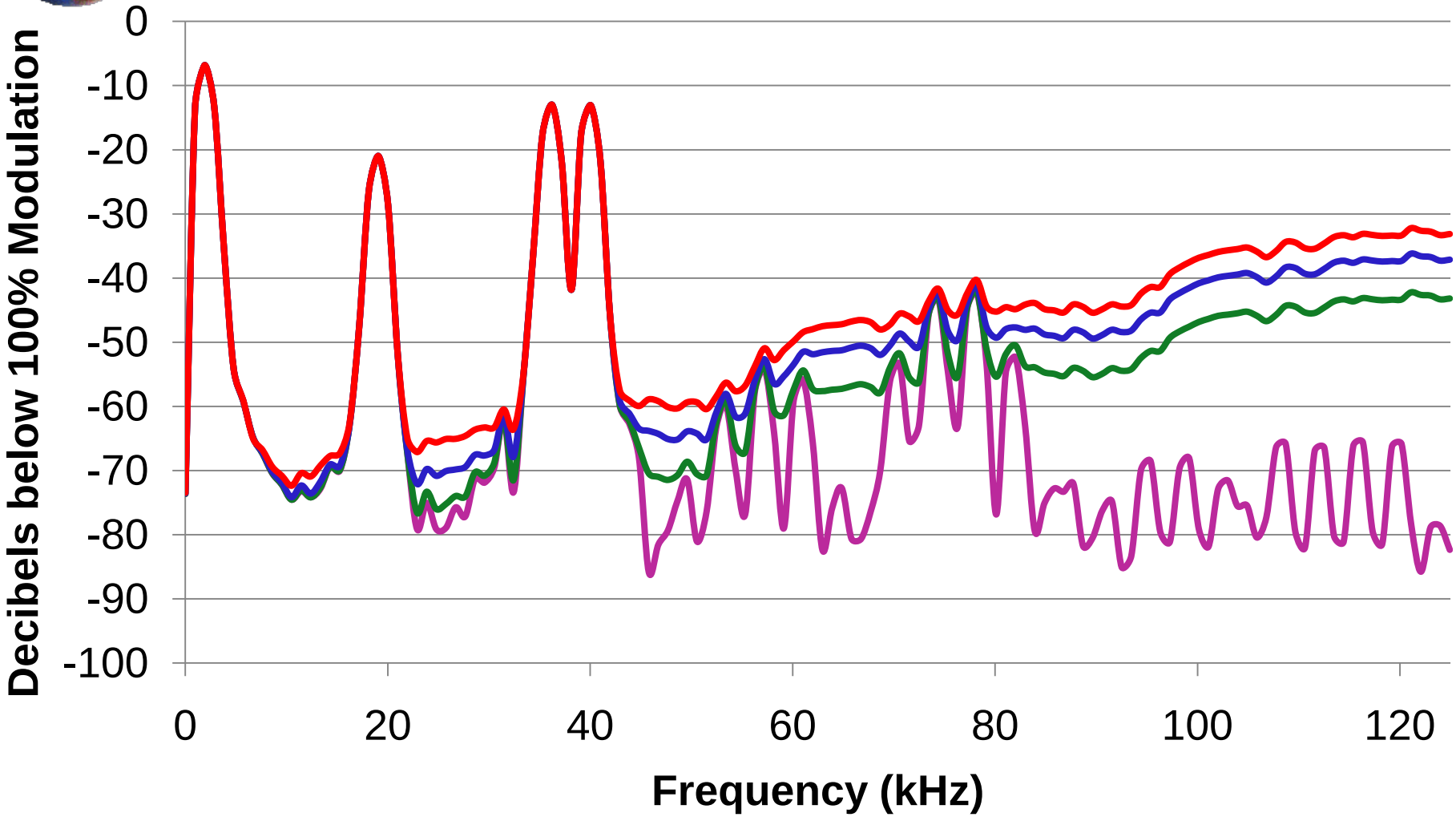
Sharp Filtered FM Composite – 1.9 kHz Mono



Demodulated FM Composite – 1.9 kHz Stereo



Sharp Filtered FM Composite – 1.9 kHz Stereo



Real World Sanity Check

Do these simulations *really* predict what happens with real FM receivers?

Tests were made with a vintage Sansui TU-9900 tuner – which has wide and narrow bandwidths

Sansui TU-9900 Tuner

Why use *this* tuner?

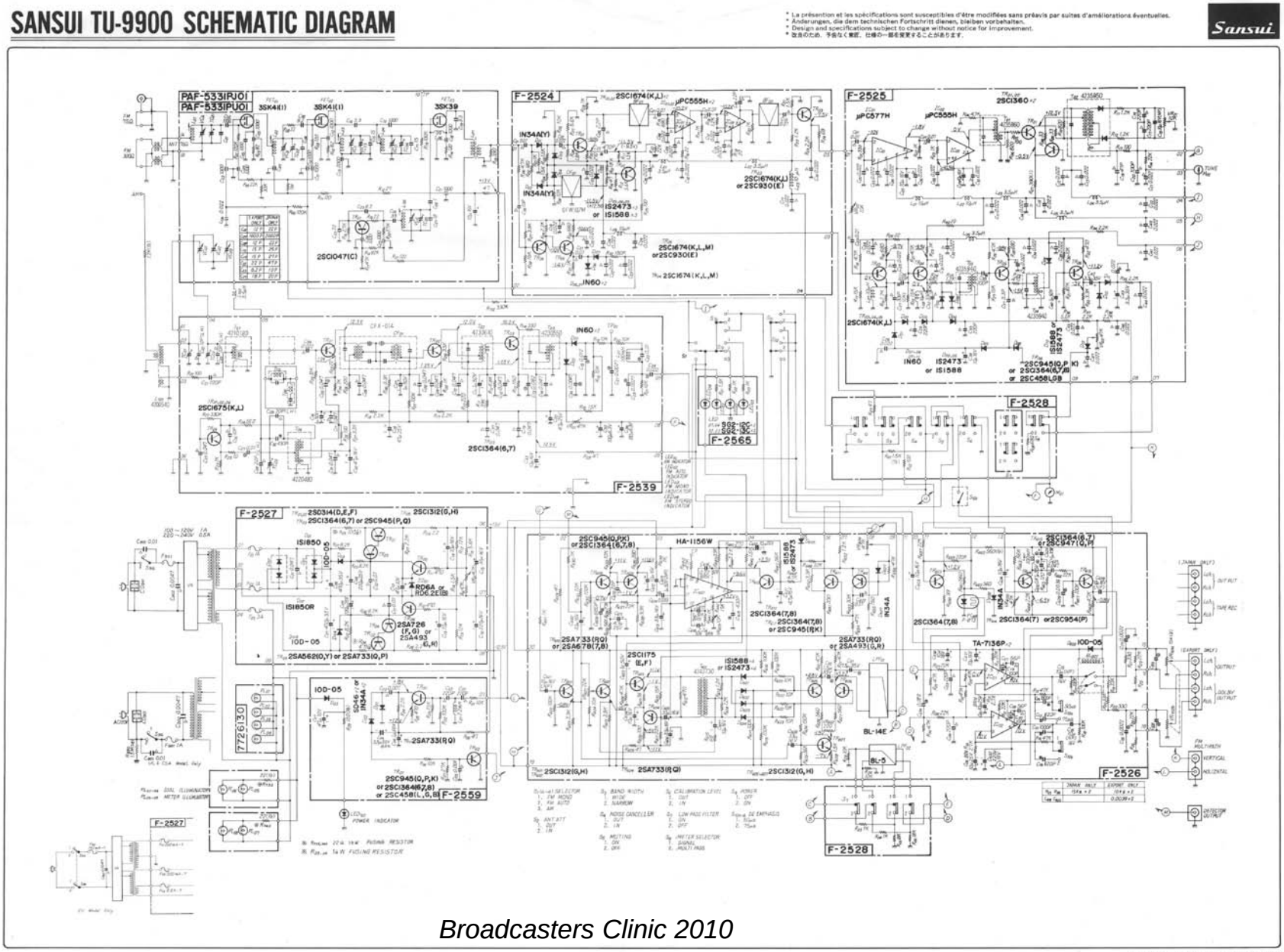
It's very good - we have lab data on it and a **schematic**

We know what it is doing with the received signal

It has selectable bandwidths

Stereo blending is switch selectable (defeatable)

Sansui TU-9900 Schematic



Sansui TU-9900 Test Results

TABLE I

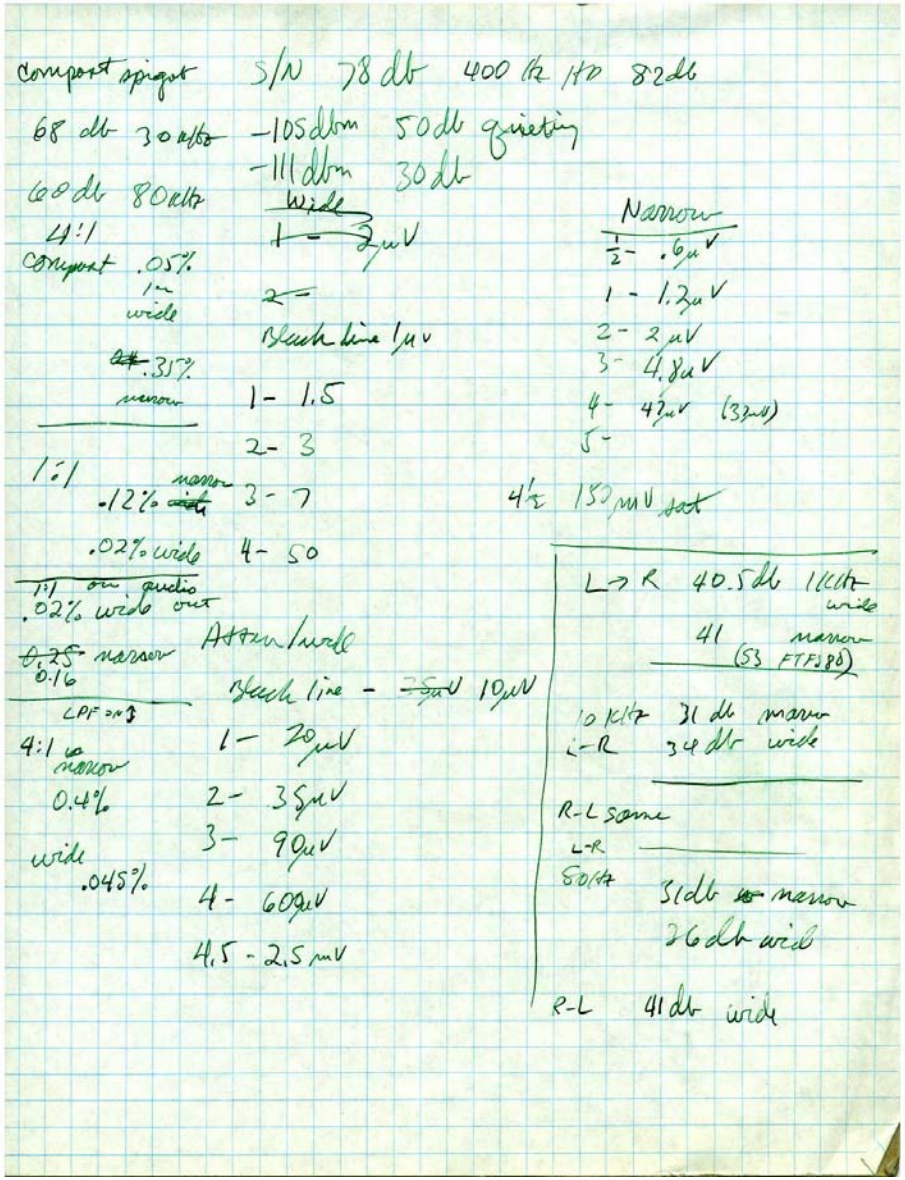
RADIO-ELECTRONICS PRODUCT TEST REPORT

Manufacturer: **Sansui** Model: **TU-9900**

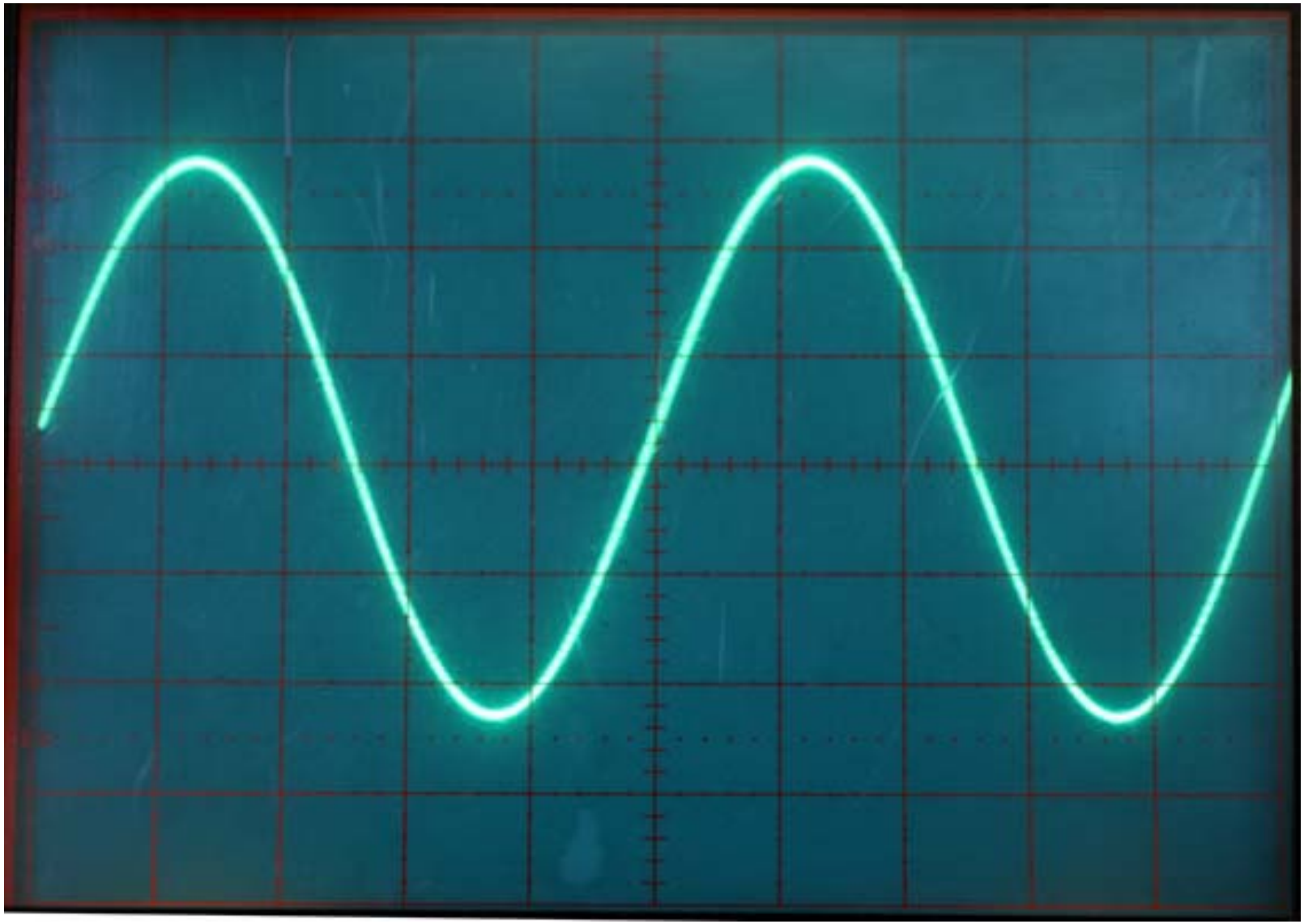
FM PERFORMANCE MEASUREMENTS

	R-E Measurement		R-E
SENSITIVITY, NOISE AND FREEDOM FROM INTERFERENCE	**WIDE**	**NARROW**	**Evaluation**
IHF sensitivity, mono: (μV) (dBf)	1.5 (9.0)	1.7 (10.0)	Superb
Sensitivity, stereo (μV) (dBf)	5.0 (19.4)	3.0 (14.9)	Excellent
50 dB quieting signal, mono (μV) (dBf)	2.2 (12.2)	2.0 (11.4)	Excellent
50 dB quieting signal, stereo (μV) (dBf)	28 (34.3)	22 (32.2)	Superb
Maximum S/N ratio, mono (dB)	84	84	Superb
Maximum S/N ratio, stereo (dB)	73	73	Excellent
Capture ratio (dB)	1.0	3.3	Excellent
AM suppression (dB)	60	—	Very good
Image rejection (dB)	100+	—	Excellent
IF rejection (dB)	100+	—	Excellent
Spurious rejection (dB)	100+	—	Excellent
Alternate channel selectivity (dB)	57	95	See Text
FIDELITY AND DISTORTION MEASUREMENTS			
Frequency response, 50 Hz to 15 kHz (±dB)	+0.3	–0.5	Very Good
Harmonic distortion, 1 kHz, mono (%)	0.037	0.20	Superb
Harmonic distortion, 1 kHz, stereo (%)	0.037	0.55	Superb
Harmonic distortion, 100 Hz, mono (%)	0.075	0.075	Excellent
Harmonic distortion, 100 Hz, stereo (%)	0.075	0.095	Excellent
Harmonic distortion, 6 kHz, mono (%)	0.075	0.65	Superb
Harmonic distortion, 6 kHz, stereo (%)	0.10	0.50	Superb
Distortion at 50 dB quieting, mono (%)	1.0	1.3	Good
Distortion at 50 dB quieting, stereo (%)	0.3	1.3	Very good
STEREO PERFORMANCE MEASUREMENTS			
Stereo threshold (mV) (dBf)	5.0 (19.3)	3.0 (14.9)	Very Good
Separation, 1 kHz (dB)	46	42	Excellent
Separation, 100 Hz (dB)	43	39	Excellent
Separation, 10 kHz (dB)	36	40	Superb
MISCELLANEOUS MEASUREMENTS			
Muting threshold (μV) (dBf)	5.0 (19.3)	3.3 (15.8)	Good
Dial calibration accuracy (±kHz @ MHz)	–.2 MHz	—	Fair
EVALUATION OF CONTROLS, DESIGN, CONSTRUCTION			
Control layout			Excellent
Ease of tuning			Superb
Accuracy of meters or other tuning aids			Excellent
Usefulness of other controls			Very Good
Construction and internal layout			Excellent
Ease of servicing			Excellent
Evaluation of extra features, if any			Superb
OVERALL FM PERFORMANCE RATING			Excellent

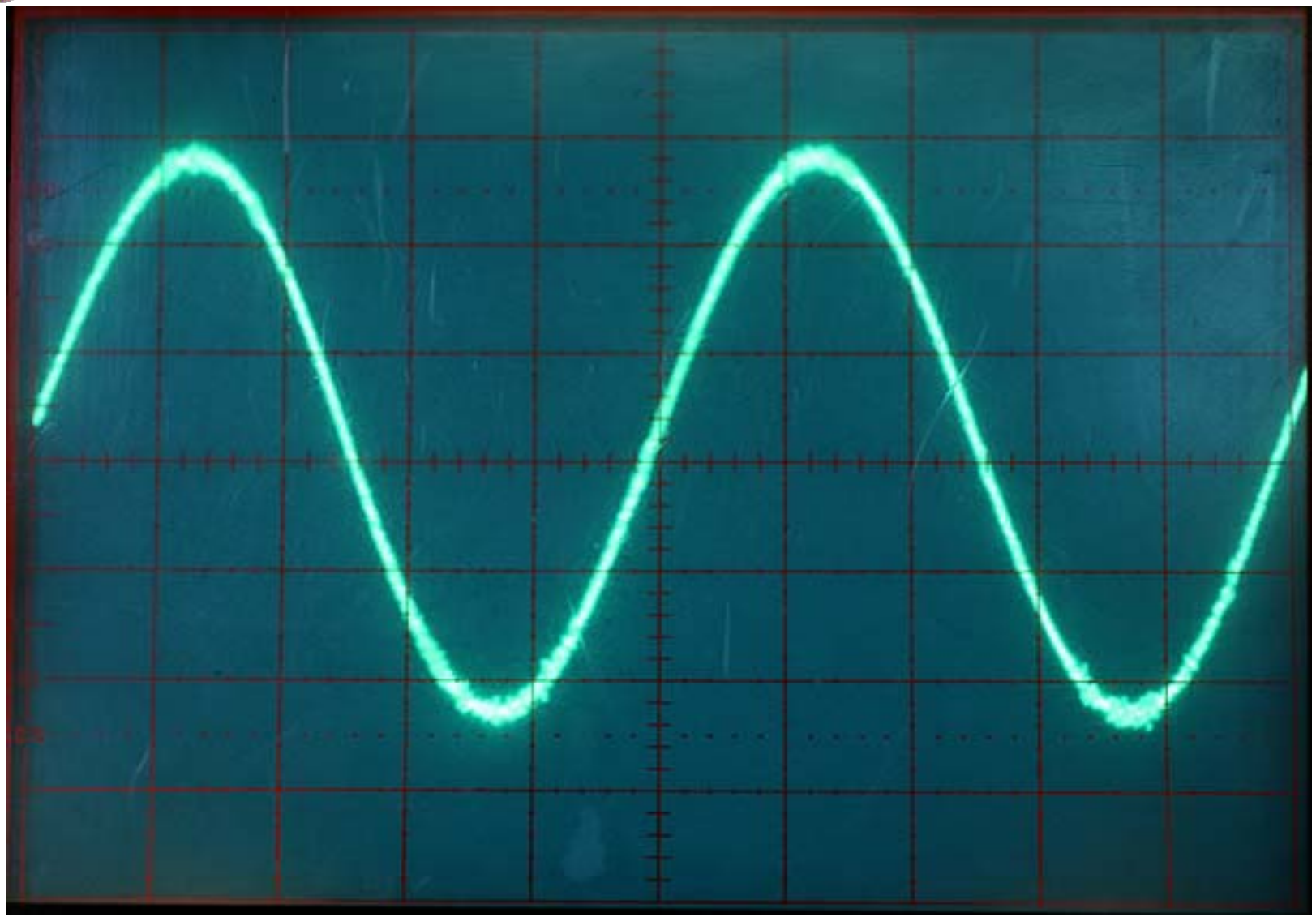
Sansui TU-9900 Lab Tests - 1977



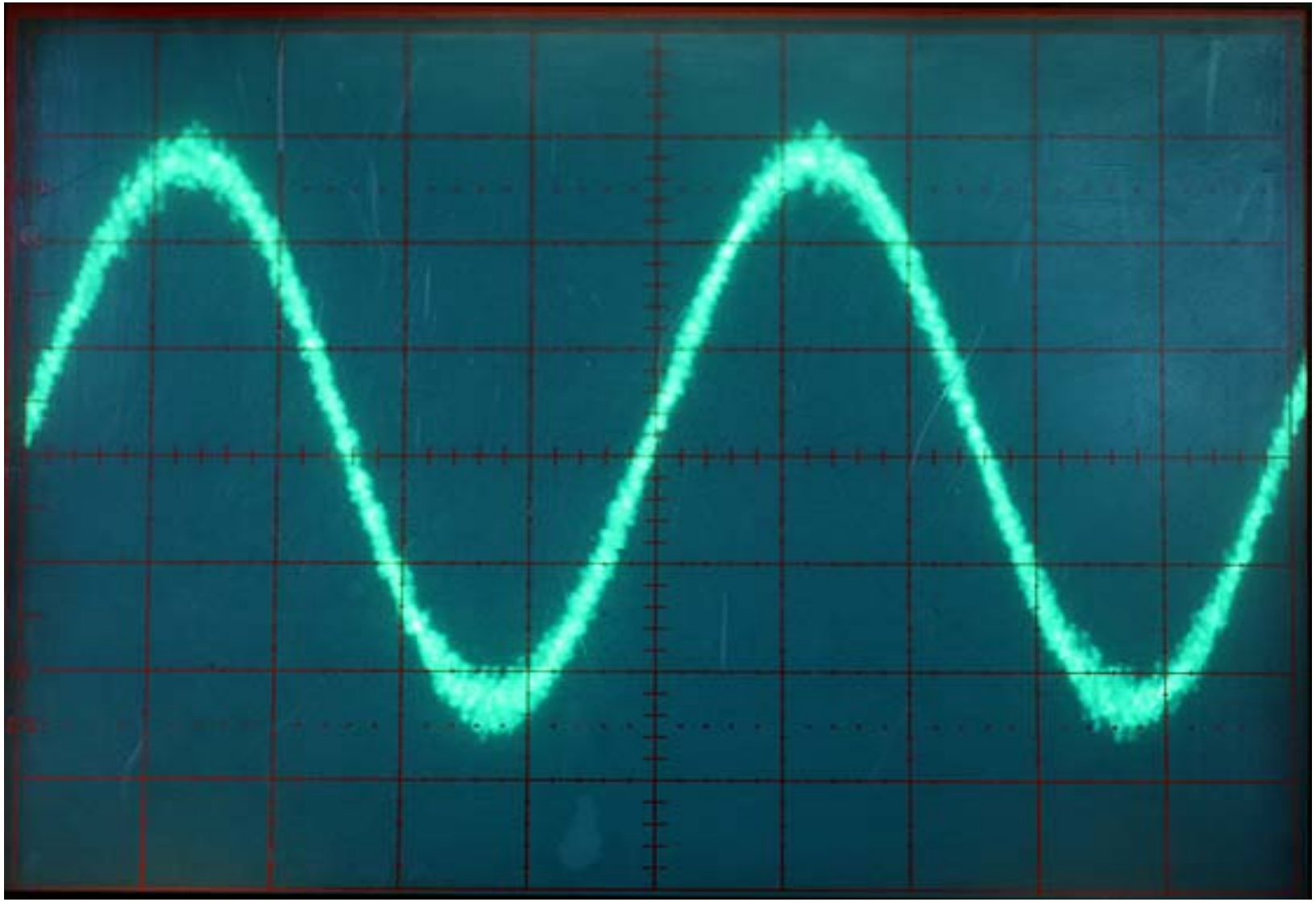
Composite output, 400 Hz tone, no HD



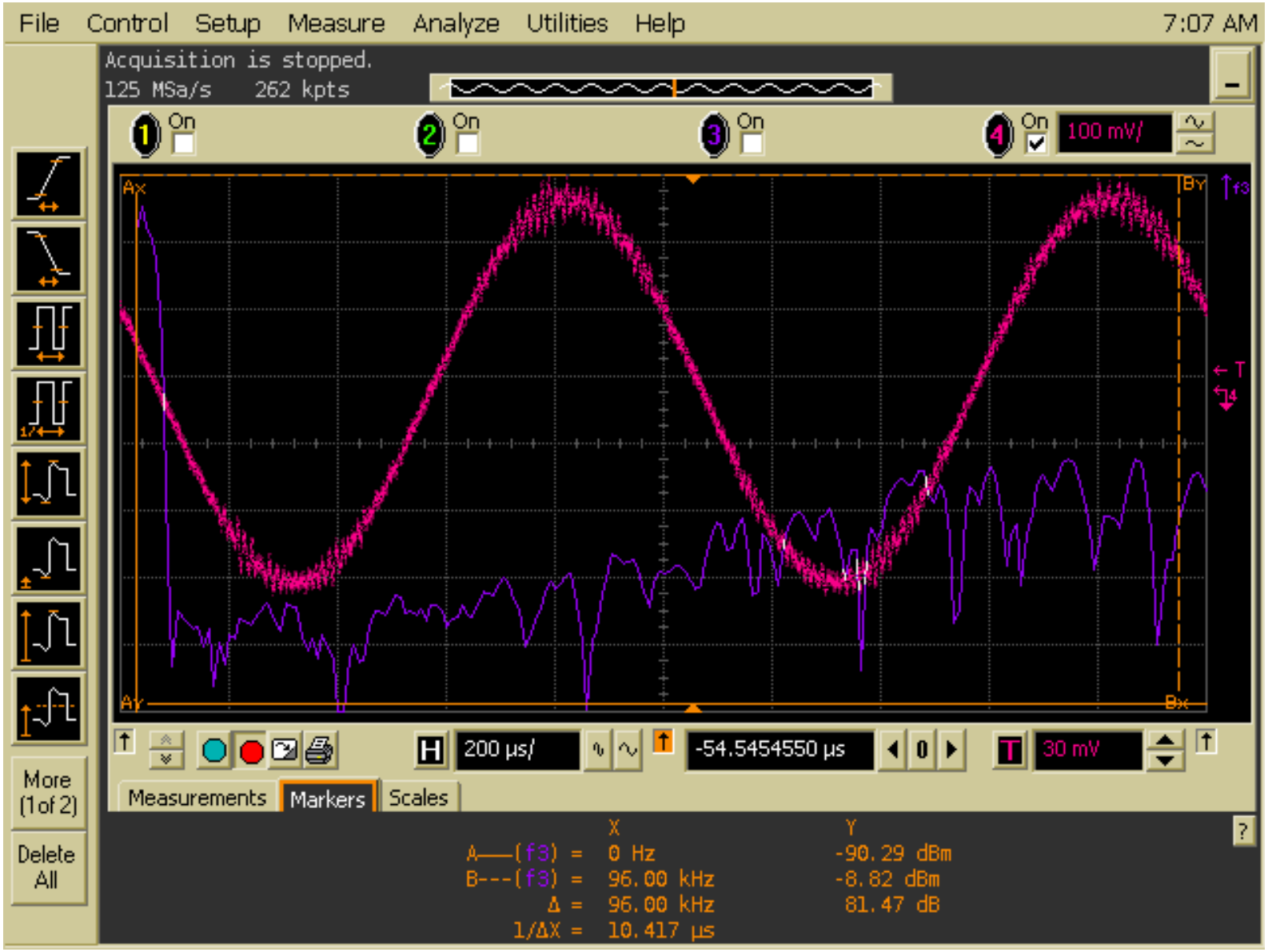
Composite, 400 Hz tone, 4% HD, narrow IF



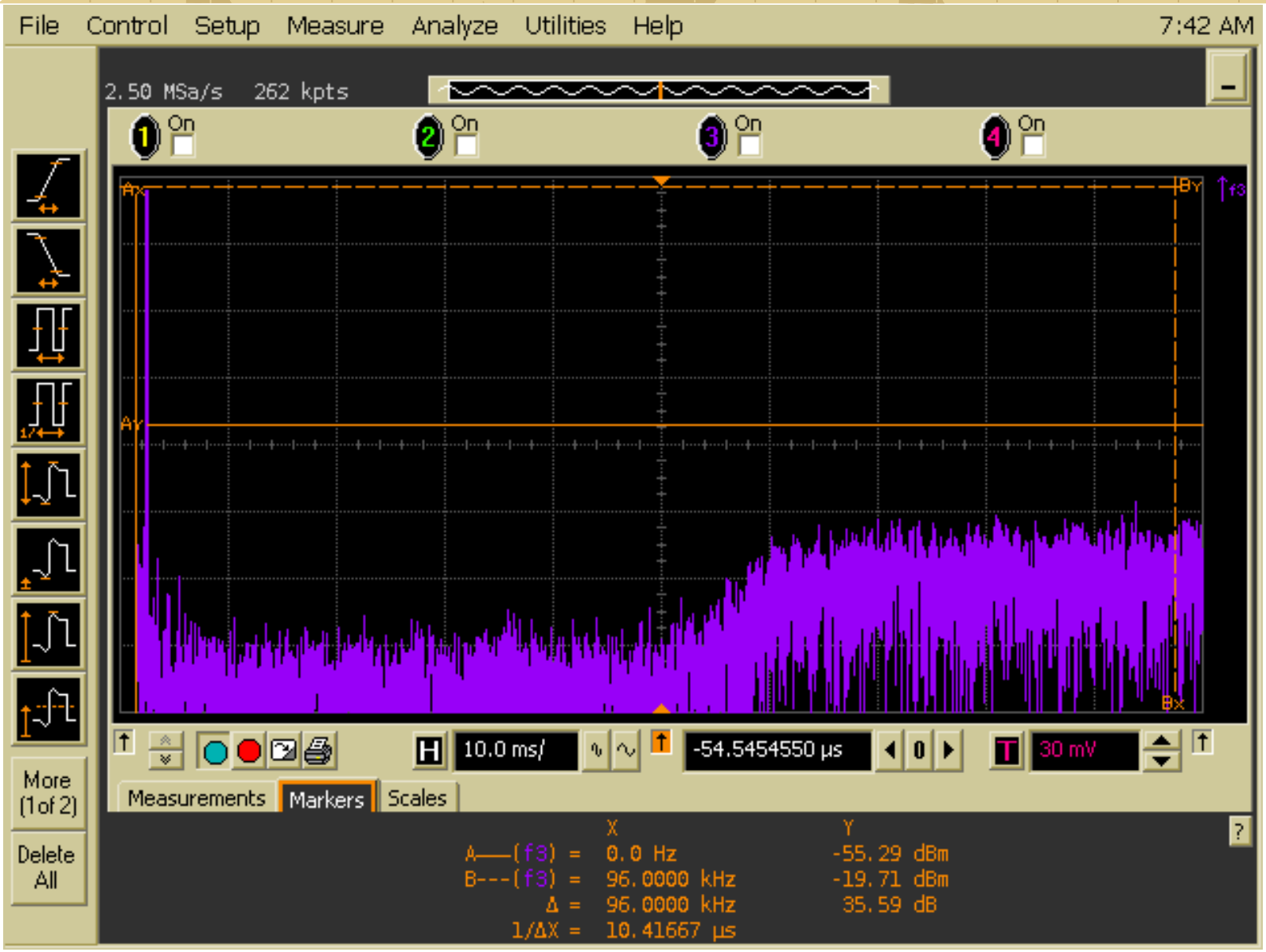
Composite, 400 Hz tone, 4% HD, wide IF

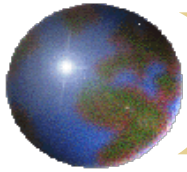


Composite, 1 kHz tone, 10% HD, wide IF



Composite, 1 kHz tone, 10% HD, wide IF





Real World Sanity Check

Sanity check:

PASS!

What do the simulation plots tell us?

- The first order beats are not the only significant components of self-noise
- Higher order terms increase twice as fast in dB with increasing digital power
- Sharp filtering in receivers reduces, but does not eliminate self-noise
- The stereo L-R, RDS, and SCA spectral areas are most affected by self-noise. FM mono is robust.

Composite SNR (53 kHz) vs. Digital Power
1.9 kHz monophonic tone

Digital Power	Composite SNR, no IF filter	Composite SNR, sharp IF filter
1%	50.0 dB	54.1 dB
4%	42.8 dB	48.4 dB
10%	36.9 dB	44.3 dB

FM SNR Relationships

for 75 microsecond emphasis – assuming white noise

Given composite SNR in 53 kHz bandwidth:

Add 29.6 dB to get mono SNR

Subtract 23.0 dB from mono SNR to get stereo SNR

Composite, Mono, and Stereo SNR

	Wideband IF			Sharp IF		
Digital Power	Composite SNR (wide IF)	Mono SNR (wide IF)	Stereo SNR (wide IF)	Composite SNR (sharp IF)	Mono SNR (sharp IF)	Stereo SNR (sharp IF)
1%	50.0 dB	79.6 dB	56.6 dB	54.1 dB	83.7 dB	60.7 dB
4%	42.8 dB	72.4 dB	42.8 dB	48.4 dB	78.0 dB	55.0 dB
10%	36.9 dB	66.5 dB	43.5 dB	44.3 dB	73.9 dB	50.4 dB

Notes: (1) values are approximations assuming white noise
(2) Values are dynamic SNR in presence of 1.9 kHz mono tone

Sansui Stereo SNR with Wide IF, 10% HD

Conventionally measured (no FM) SNR: 46.5 dB

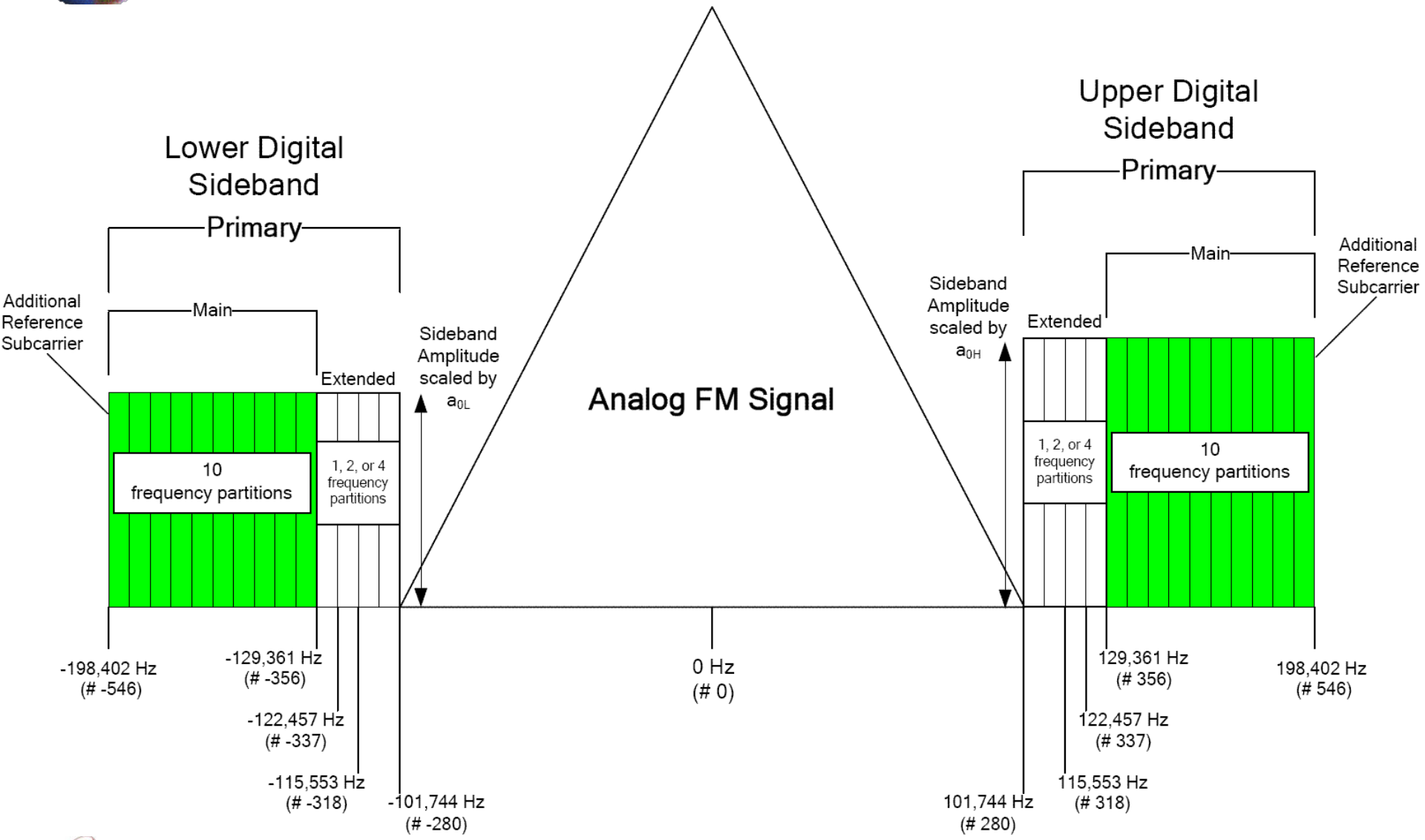
Dynamic SINAD (with 1 kHz tone): 41 dB

Tuner measurement with no HD: 73 dB

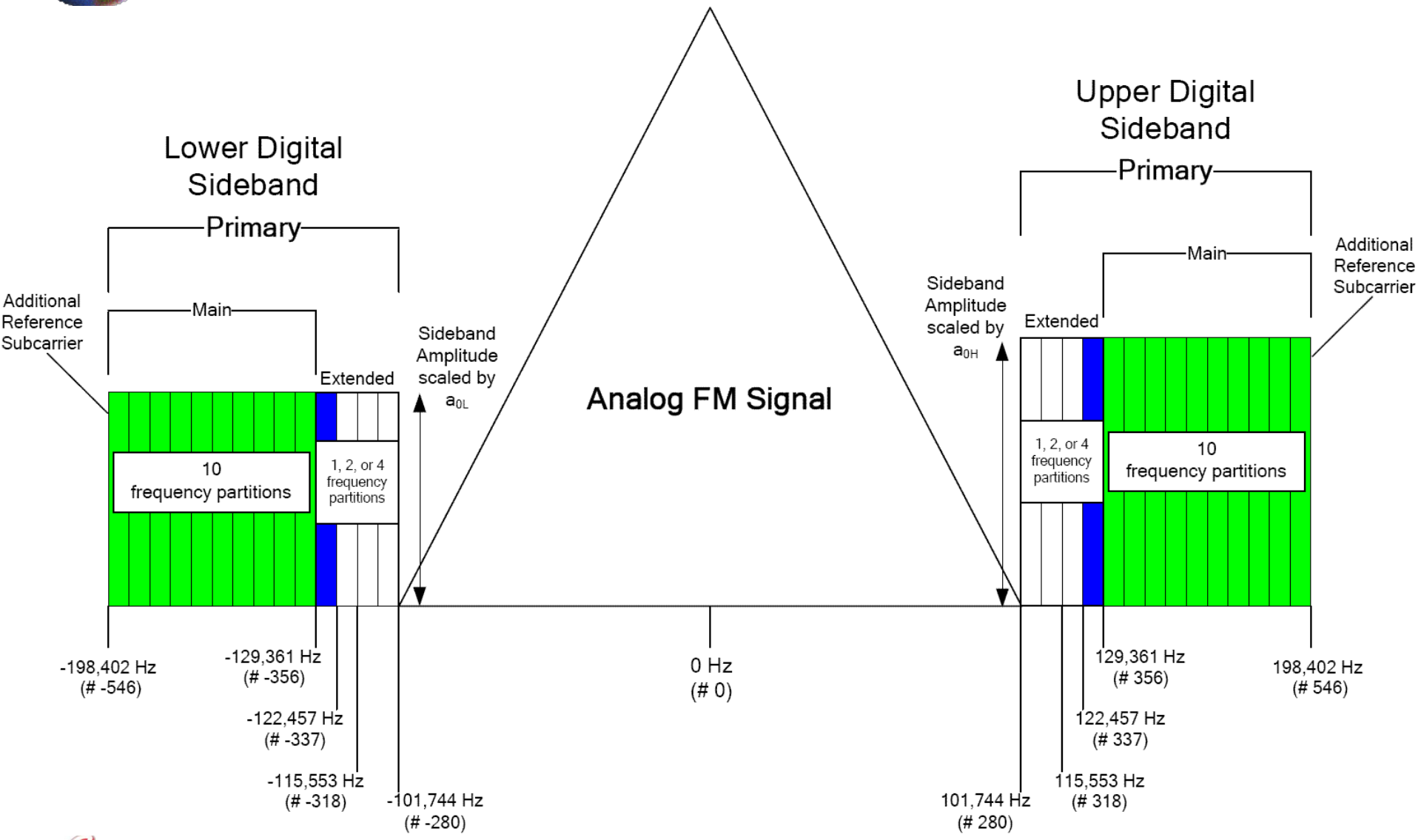
Extended Hybrid Modes

- **What we just analyzed is NOT the worst case.**
- **The worst case would be:**
  - Wideband tuner
  - MP11 extended hybrid mode
  - 14% digital power

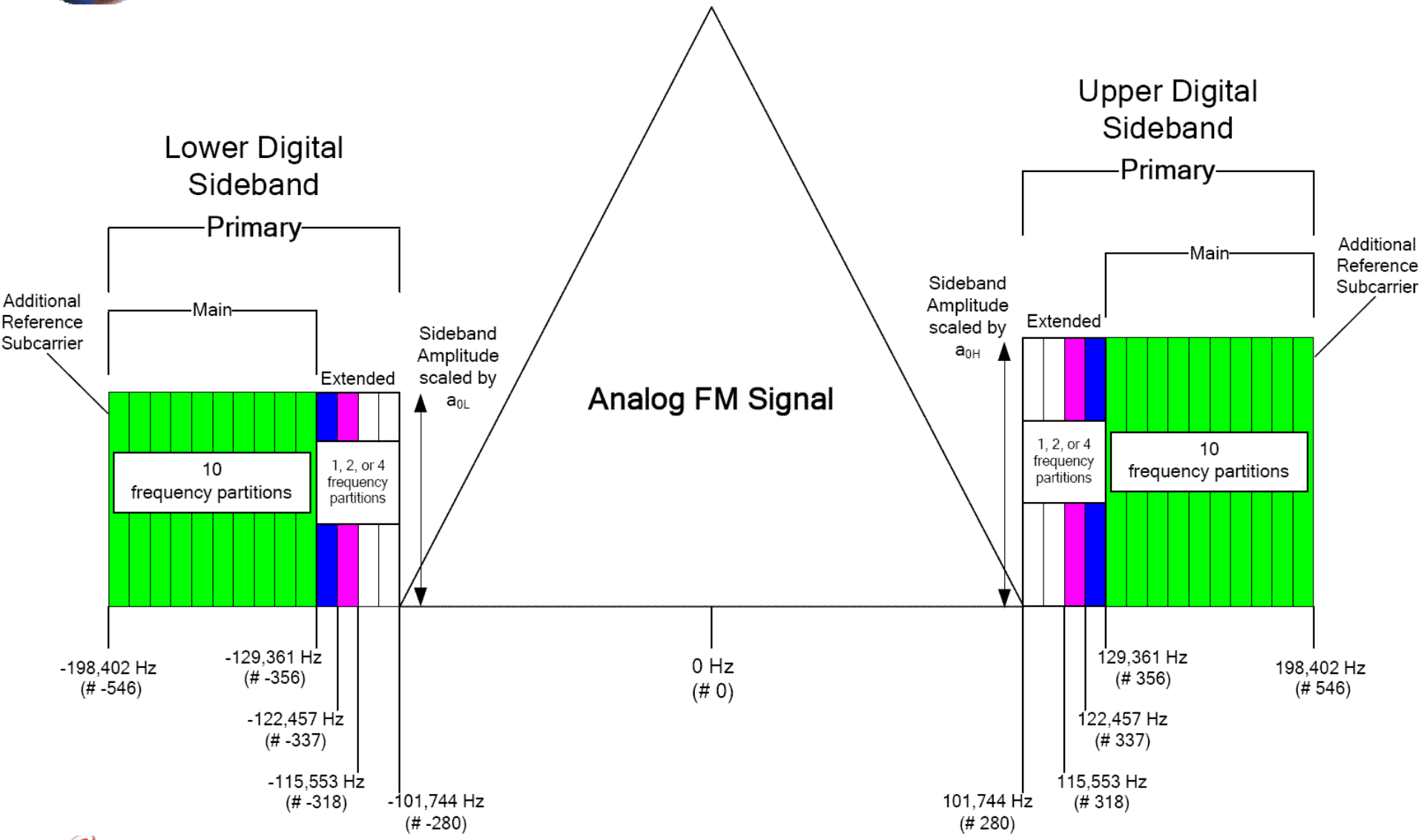
MP1 Hybrid Mode



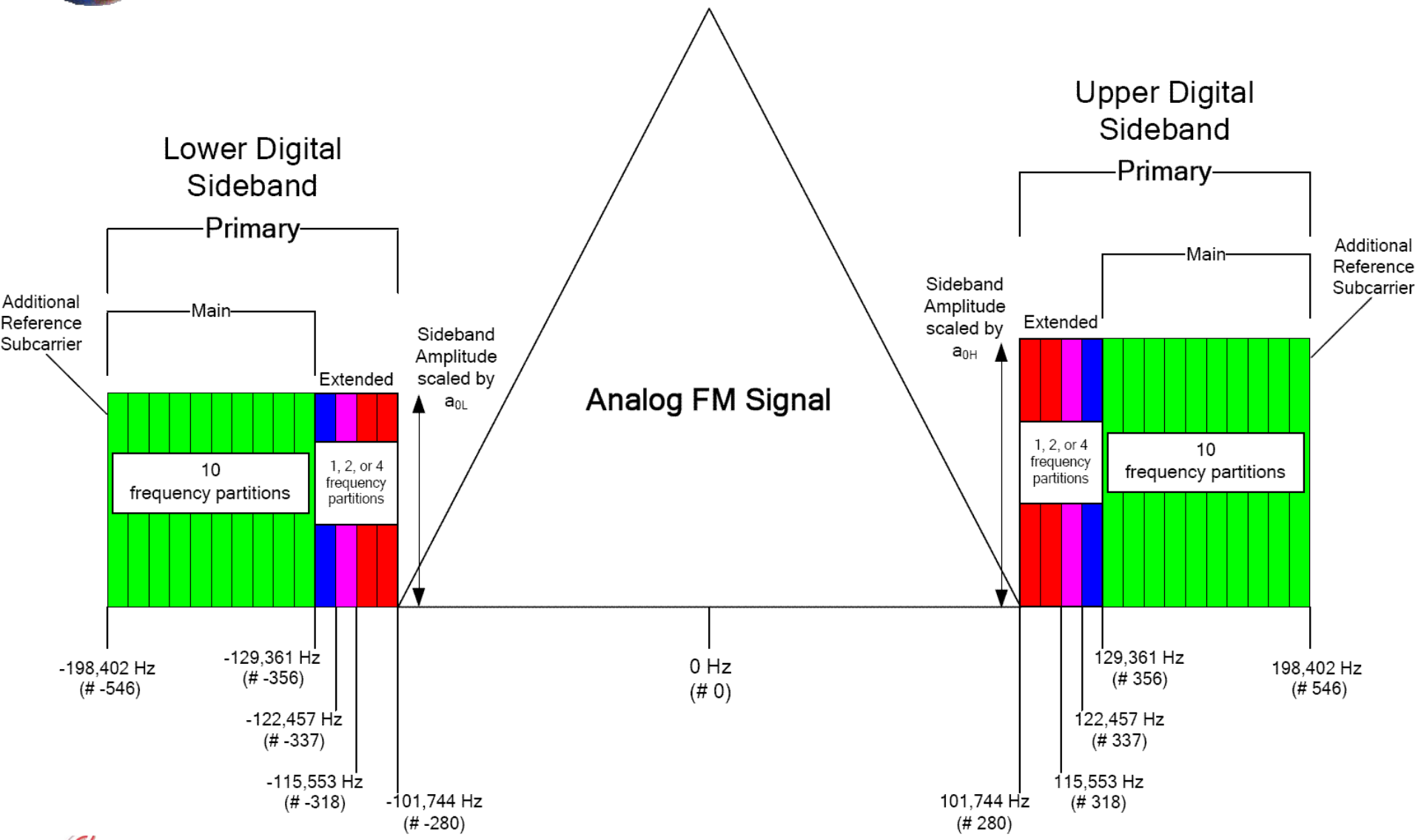
MP2 Extended Hybrid Mode



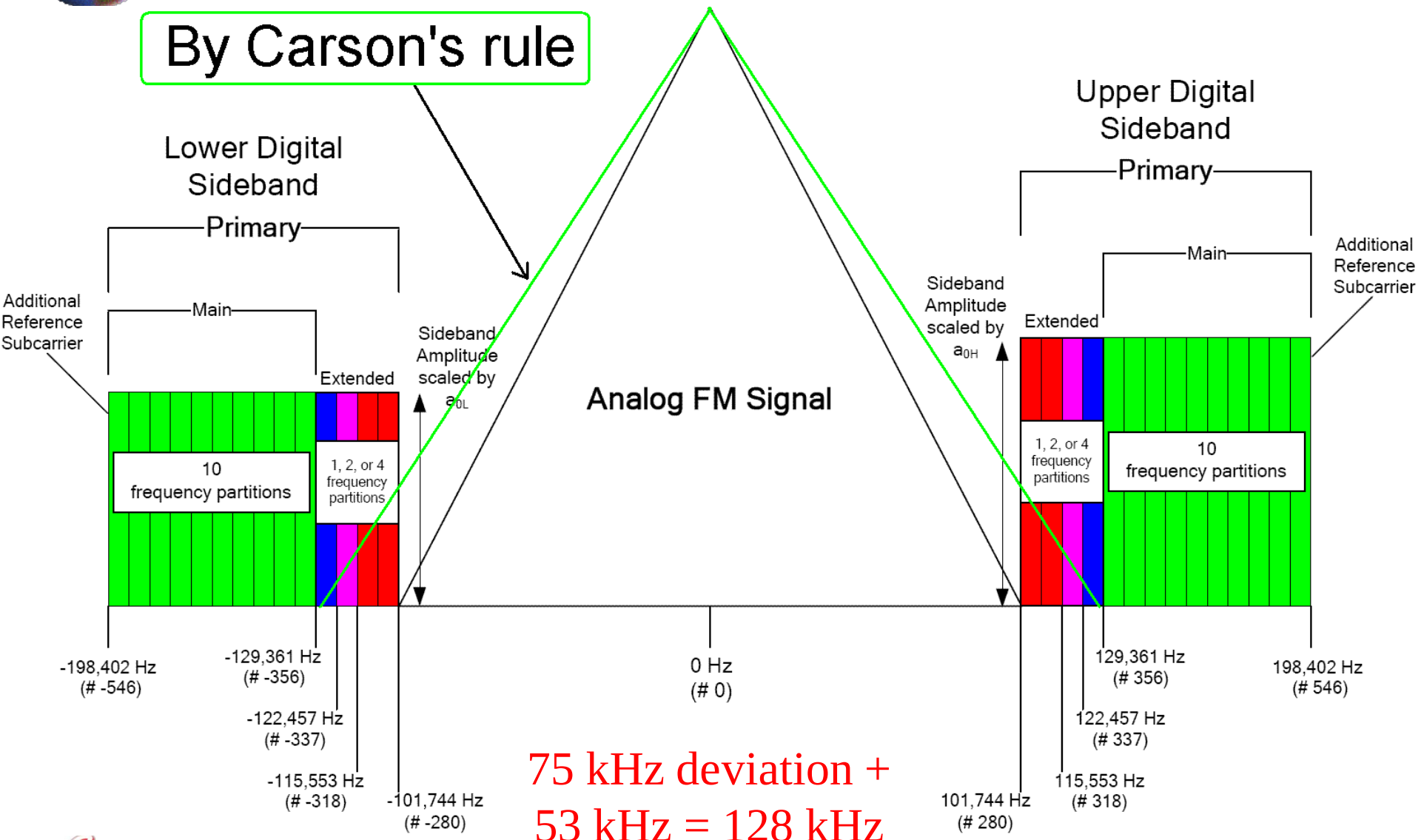
MP3 Extended Hybrid Mode



MP11 Extended Hybrid Mode



MP11 Extended Hybrid Mode



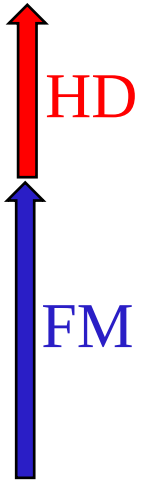
75 kHz deviation +
53 kHz = 128 kHz

Extended Hybrid Modes

- If you anticipate using an extended hybrid mode, be sure to include it in your subjective testing!

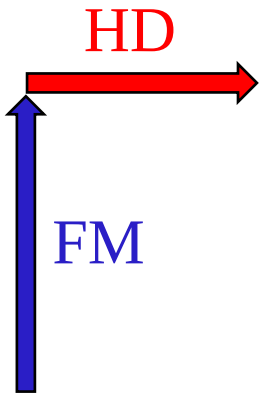
Crest Factor Reduction

It's not just for positive peak control!



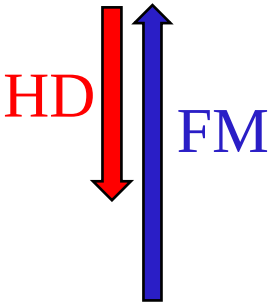
HD and FM in phase – positive envelope modulation

Reduction benefits transmitters



HD and FM in quadrature – maximum phase modulation

Control reduces self-noise peaks



HD and FM out of phase – negative envelope modulation

Reduction benefits receivers

Reducing digital crest factor has benefits for all phases – not just positive envelope peaks

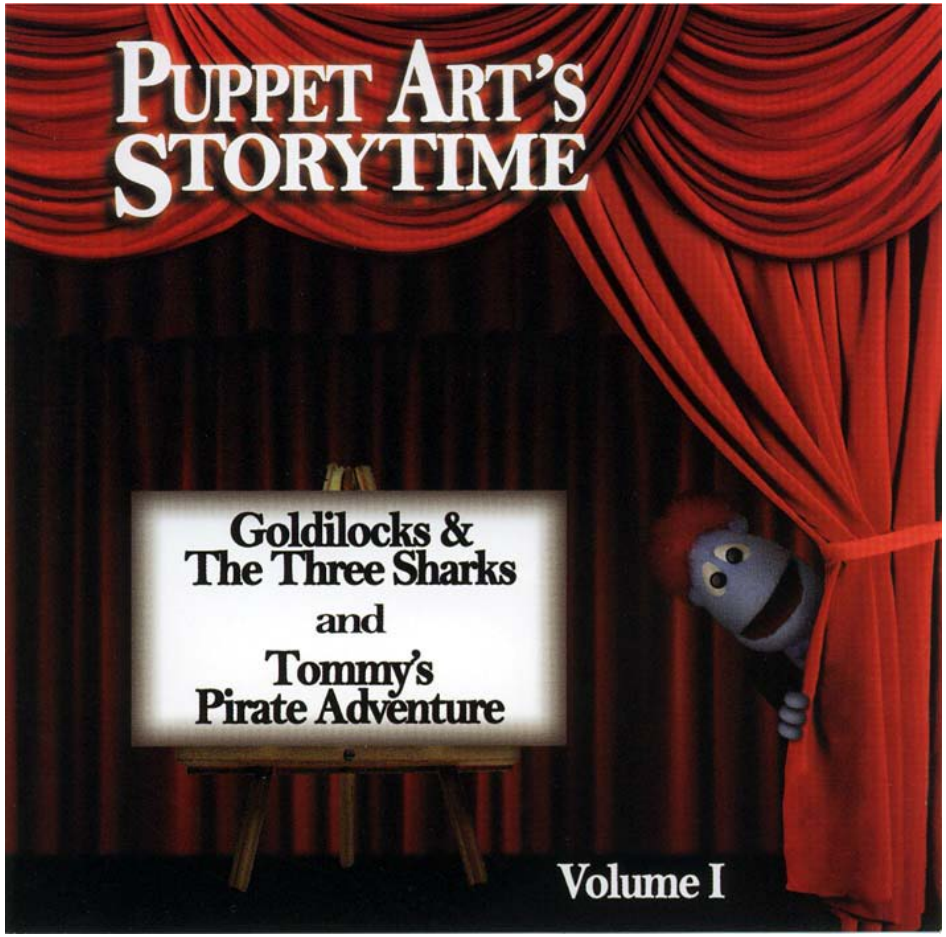
We like Ibiquity's crest factor reduction system!

Subjective Evaluation

- **SO WHAT DOES IT SOUND LIKE, ANYWAY?**
  - Tests with Sansui tuner
  - Wide & narrow IF bandwidths
  - Speech, Classical, Rock
  - Optimod 8500, 802^{EX} FM/HD exciter
  - -36 dBm into tuner, attenuator on
  - Uncompressed WAV files
  - MP1 mode only (less encroachment than extended hybrid modes)

Speech Test – Wideband IF

- Optimod is in NEWS/TALK factory preset mode
- Each segment repeats first with analog only, then analog + 10% HD
- Wide IF bandwidth

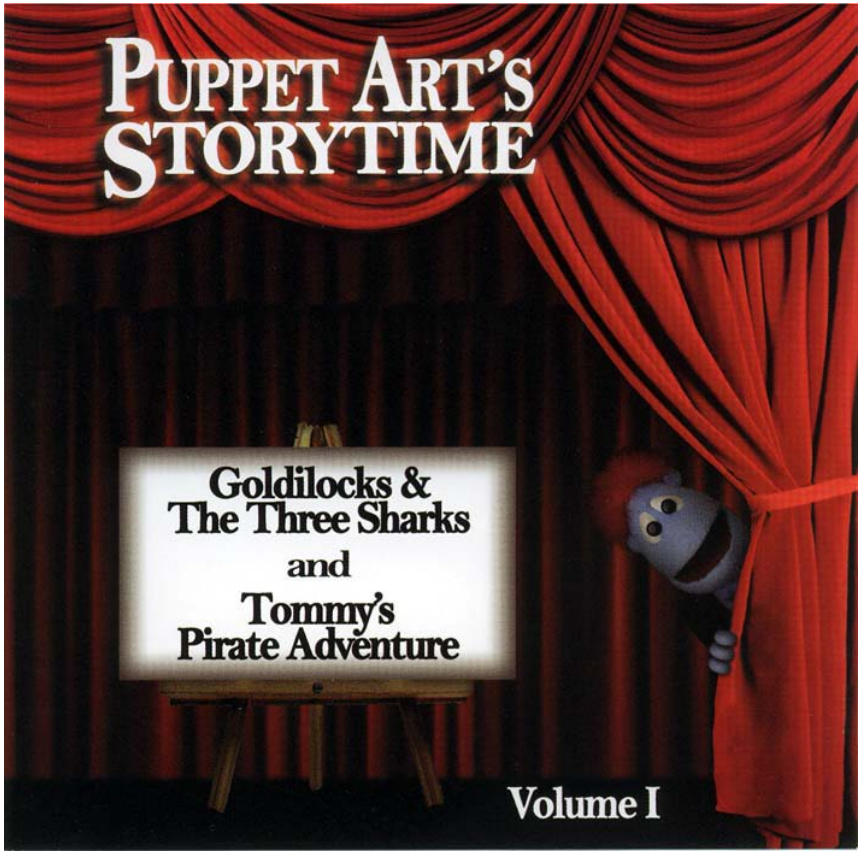


1:06

Speech Test – Narrow IF

- Optimod is in NEWS/TALK factory preset mode
- Each segment repeats first with analog only, then analog + 10% HD
- NARROW IF bandwidth

1:06



L-R Speech Test – Wideband IF

- Optimod is in NEWS/TALK factory preset mode
- Each segment repeats first with analog only, then analog + 10% HD
- Wide IF bandwidth
- Source is mostly mono; distortion is due to slight clipping level imbalances between L and R.
- Simulation predicts noise increases with analog deviation – this demonstration shows this effect.
- Nobody listens to the radio this way. But listening to L-R shows us what to listen for.

1:06

Classical Music Test – Wideband IF

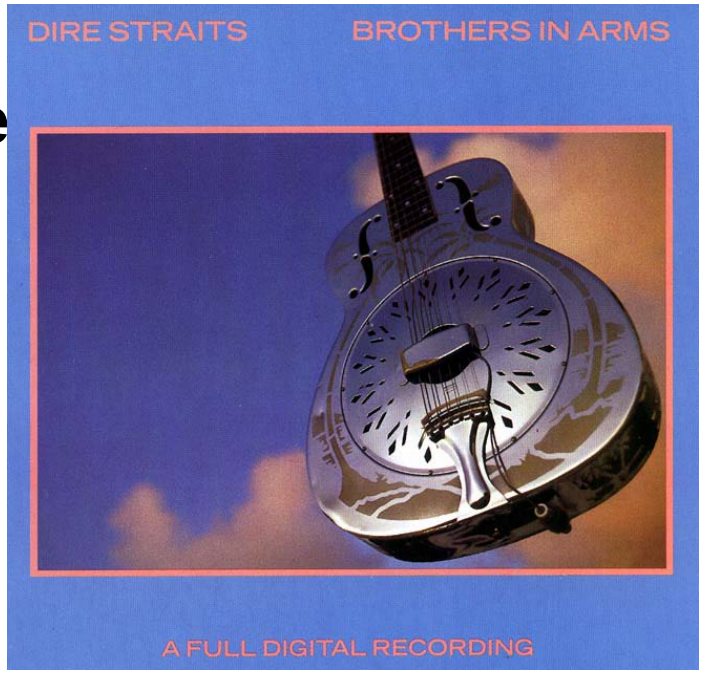
- Optimod is in Classical 5B + AGC factory preset mode
- Each segment repeats first with analog only, then analog + 10% HD
- Hi/Lo tone indicates analog only
- Lo/Hi tone indicates analog + 10% HD
- Wide IF bandwidth
- Great Mass in C Minor – Mozart (Gloria)

3:00

Rock Music Test – Wideband IF

- Optimod is in ROCK MEDIUM factory preset mode
- Each segment repeats first with analog only, then analog + 10% HD
- Hi/Lo tone indicates analog only
- Lo/Hi tone indicates analog + 10% HD
- Wide IF bandwidth
- Dire Straits – The Walk of Life

2:09



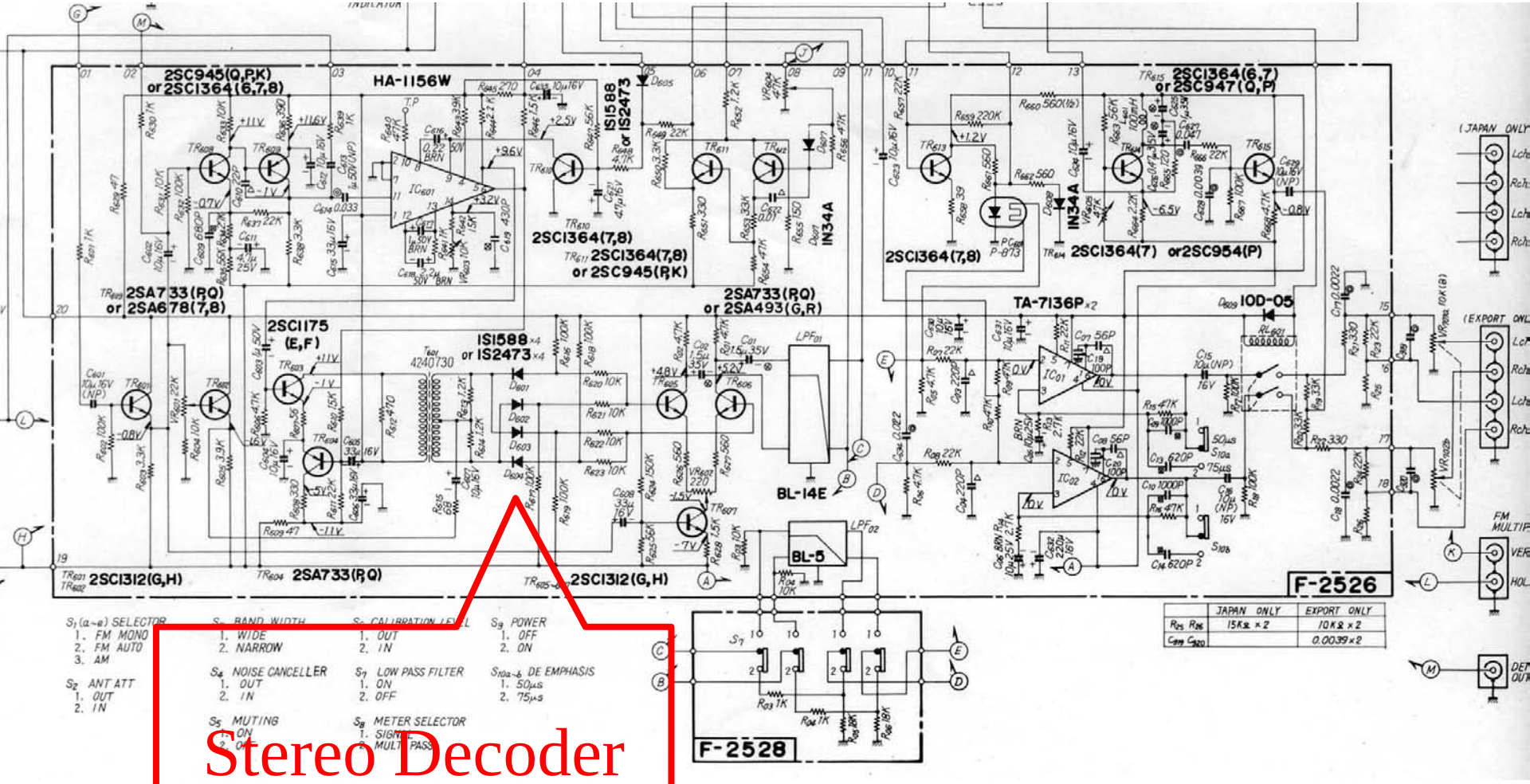
Conclusions?

- You have to make your own conclusions!
- We CAN say that there is a wide range of subjective results.
- This is why every broadcaster should do similar tests with the program material and audio processing they already use.
- Use a variety of receivers for your testing
- Turn it up enough, but not too much!
- There is no “one size fits all” here.

OTHER RESOURCES – Brian Beezley

- What about squarewave stereo decoders that respond to 3 x 38 kHz?
- http://ham-radio.com/k6sti/index.html
- HD Radio self-noise
- HD Radio self-noise levels
- IF filters and HD Radio self-noise
- Postdetection filter for HD Radio signals
- Harmonic cancellers for HD Radio signals
- HD Radio time & level alignment

Sansui Stereo Decoder Schematic



Stereo Decoder
Ring Modulator

Decisions for Broadcasters

- **TURN IT UP!**
  - Turn it up ENOUGH
    - Enough means providing the digital coverage you need
  - Don’t turn it up TOO MUCH
    - Too much means causing self noise interference or multipath susceptibility to analog

Decisions for Broadcasters

- **How much is *too much*?**
  - Format dependent
  - Classical format or other wide dynamic range material is least tolerant of self-noise
  - Aggressively processed analog is most tolerant of self-noise because of masking
  - Multipath propagation – terrain – may limit digital power
  - Road noise will dominate self-noise in cars
  - Receiver blending will mitigate noise & multipath
  - Mono reception is mostly unaffected

Caution

- **Don’t overdeviate your analog FM!**
- **PAR reduction systems should reduce both positive *and* negative envelope modulation**
  - **Don’t pinch off the FM envelope!**

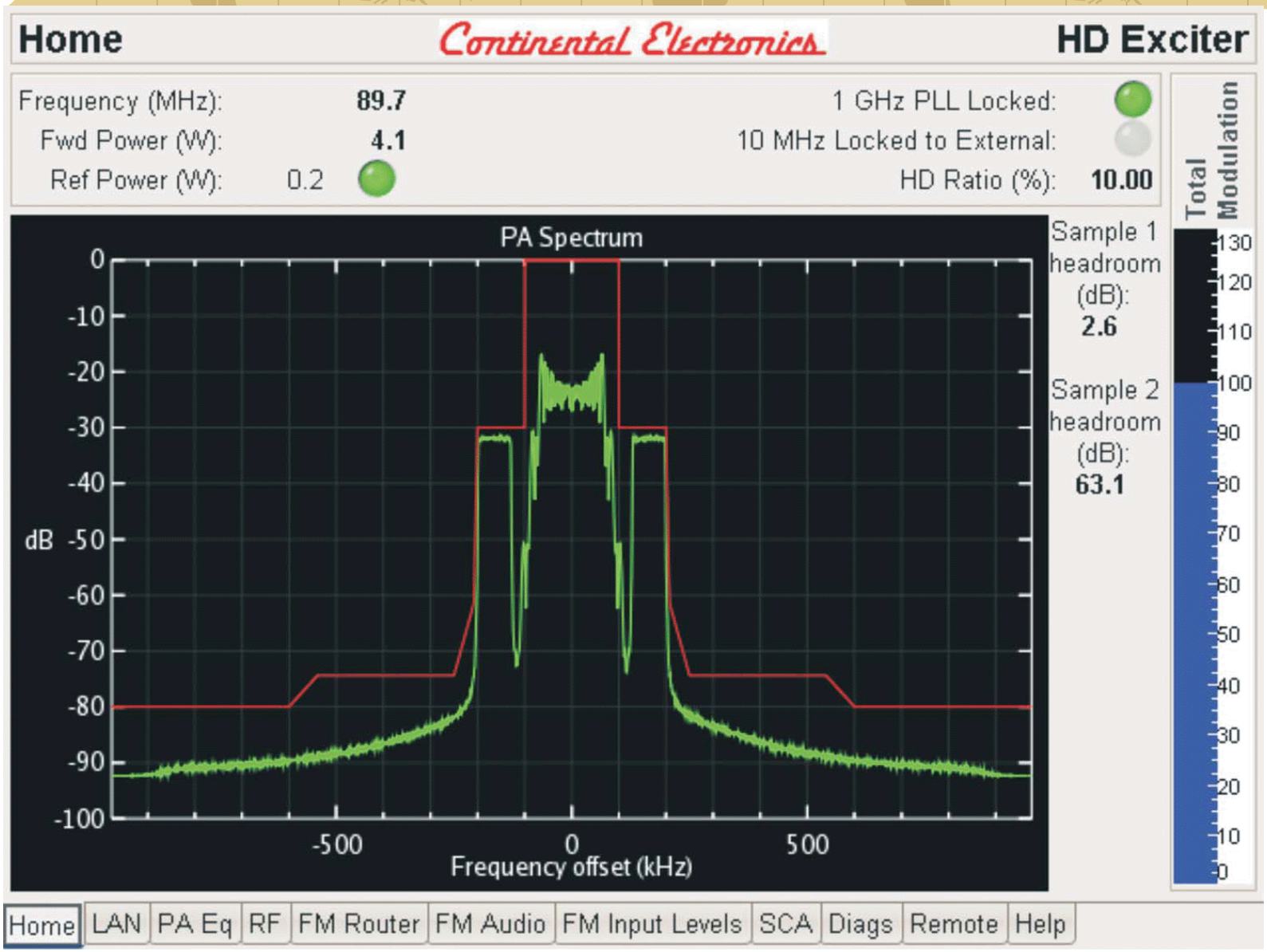
Suggestions

- **Common amplification benefits extend to 4% and 10% power**
  - **Keep it simple!**
  - **Reasonable efficiency as signal statistics approach those of digital television**
  - **No dual feedlines or dual antennas required**
  - **No circulators required**
  - **No filter group delay distortion**
- **Tube technology is most economical for achieving high PEP for elevated HD power**

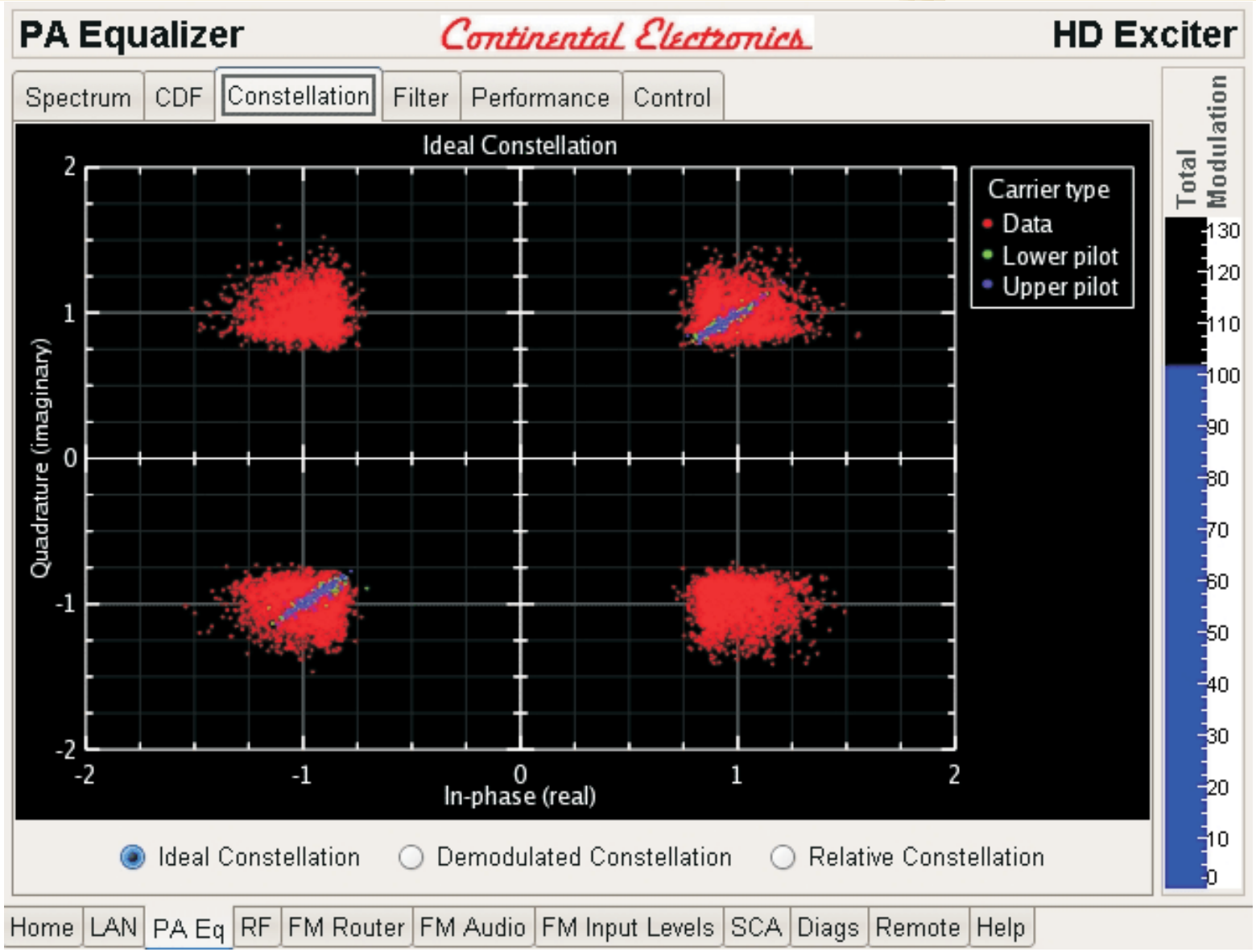
Suggestions (continued)

- **Water cooling is an option for limited space or air conditioning load**
- **Power handling of coax, combiners, filters, and antenna – mainly PEP ratings**
- **Make use of the diagnostics and signal analysis functions built in to the exciter – such as Continental's *Insight* system**

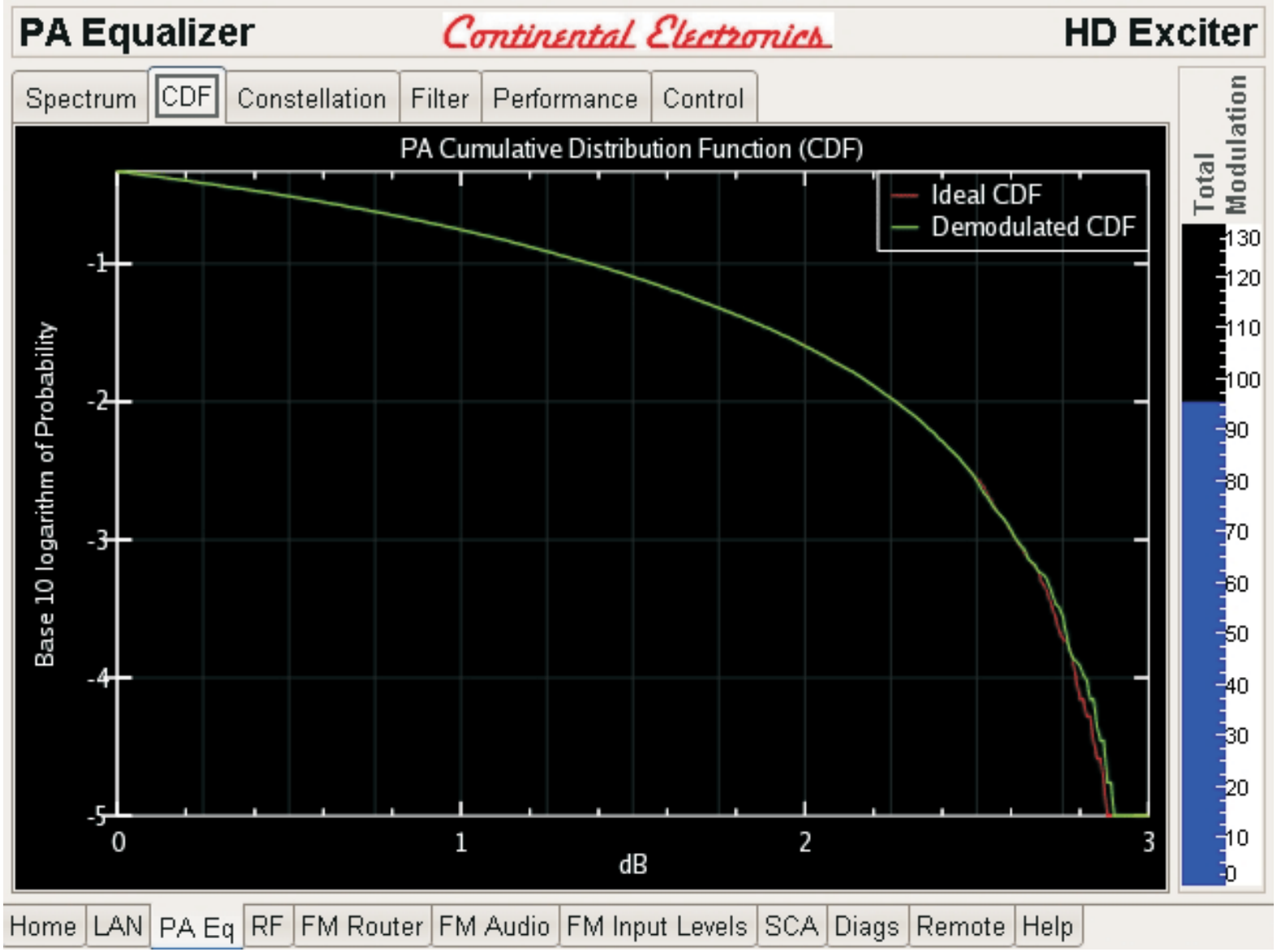
Insight System – RF Spectrum Display



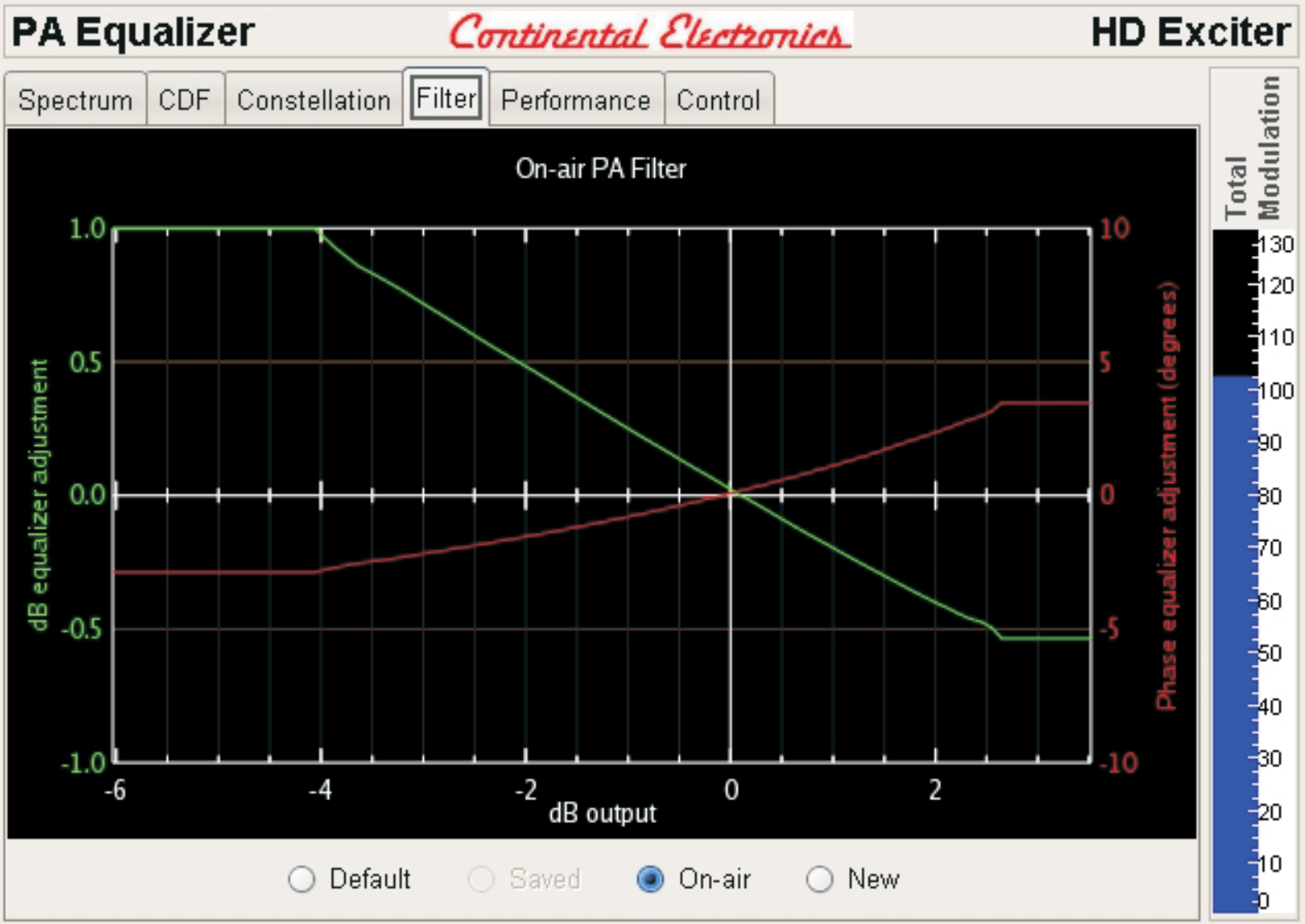
Insight System – Demodulated Constellation



Insight System – CDF Probability Curves (PAR)



Insight System – Demodulated Constellation



Conclusions – Digital Power Increase

- It's a tradeoff
- Engineering is all about tradeoffs
- Every station is different, and requires good engineering decisions
- Good engineering decisions require good information – we hope this information helps you

Thank You!

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