

# **High Q Tunable RF Filters For Next Generation Radio Systems**

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2 December 2021

# Agenda

- Anlotek Tunable RF Filter Essentials:
  - Basic circuit
  - Results
- Application
  - Bandpass Delta Sigma for receive at higher frequencies
- Conclusions

## Applications are everywhere in RF

### Wireless Innovation Forum Top Ten Most Wanted Innovations

- Innovation #5

“*Adaptive receive filtering* to provide better rejection of the interference balanced against possible sensitivity degradation and / or signal quality factors such as BER, etc.”

- Innovation #7

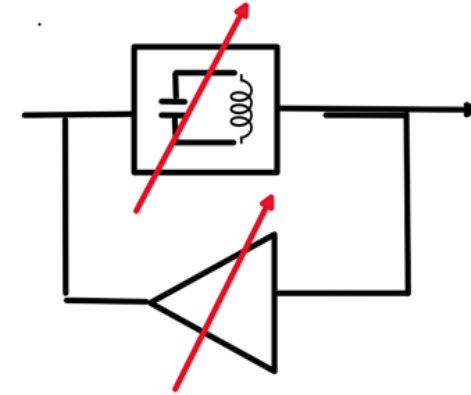
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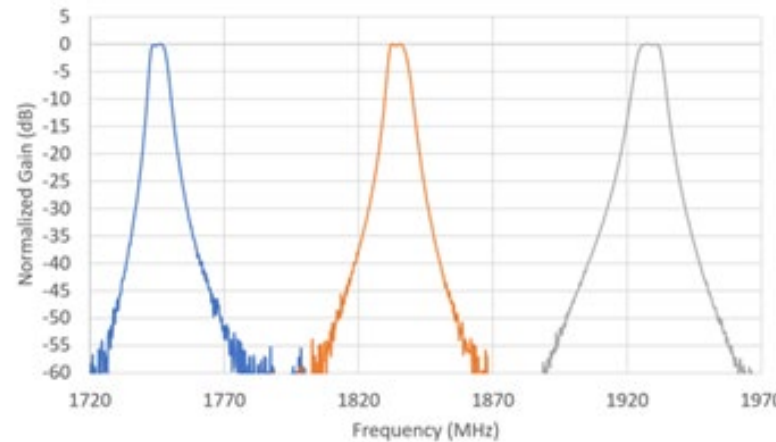
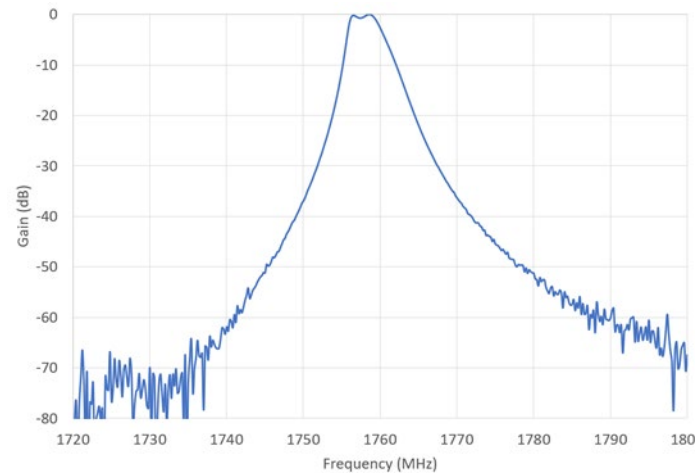


## Anlotek's Core Circuit

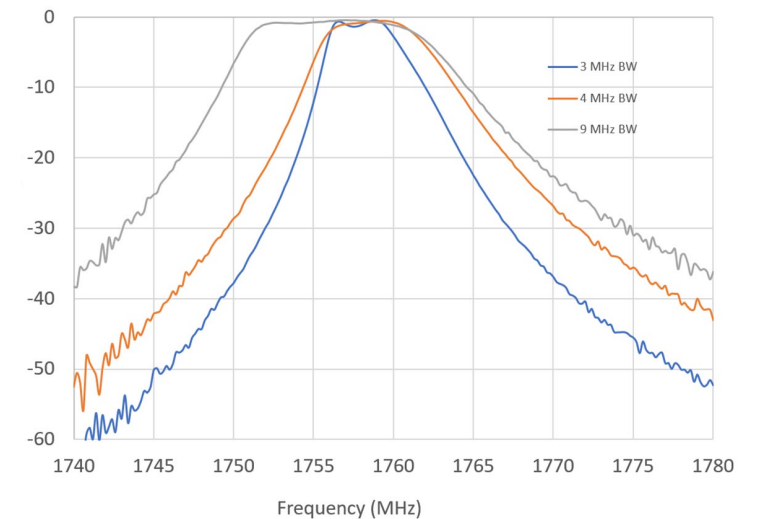
- Anlotek's tunable pole consists of:
  - variable gain  $\gg Q$
  - tunable resonance  $\gg$  center frequency
- An active circuit
  - No insertion loss
  - Noise figure: Conservatively 4.5dB with custom circuitry
  - IIP3: Determined by first pole
  - Deep out of band rejection



*Three Anlotek poles in series*

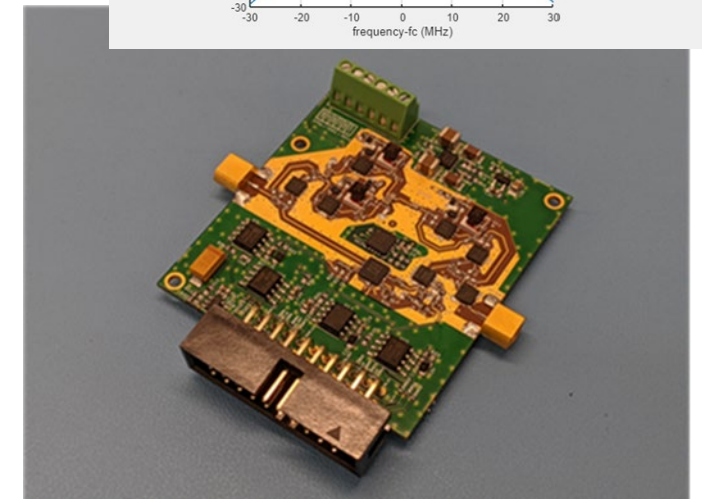
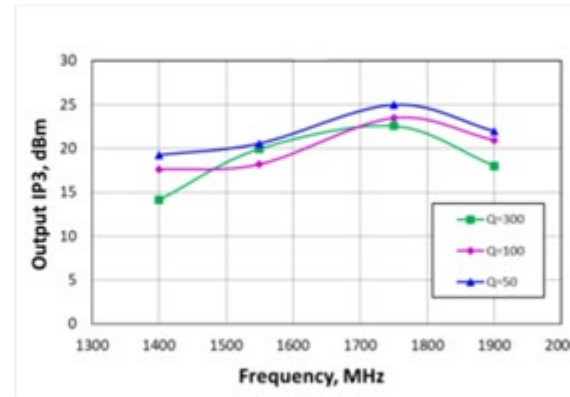
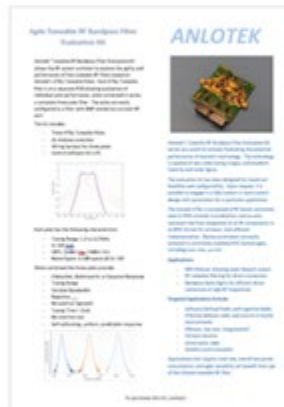
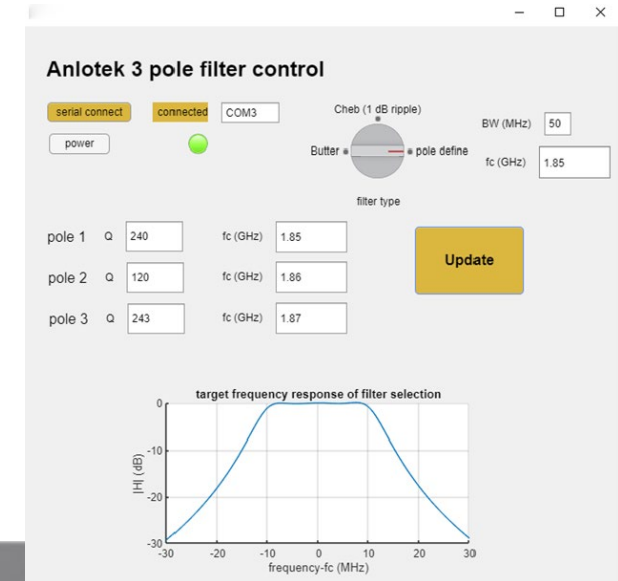


Our initial demo tunes over 20% range  
– can be redesigned to cover virtually any range



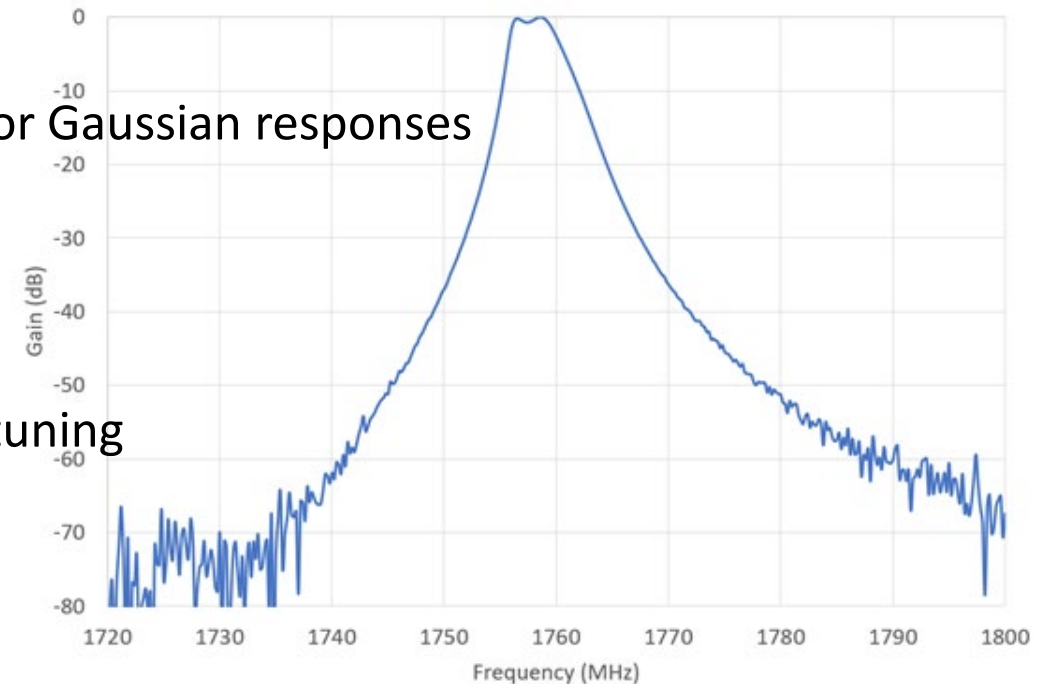
## Anlotek's Filter Evaluation Kit

- Built with COTS on FR4: Measured results
  - 1.3 to 2.07GHz tuning range
  - Each pole Q adjustable from 20 to 1000
  - OIP3: 22dBm typical, 14dBm minimum
  - Noise Figure: 6.3dB depending on frequency and Q
  - Variable bandwidth from 1MHz to 100MHz
- Offered as a three pole technology evaluation kit



## Advantages with the Anlotek Tuneable Filter

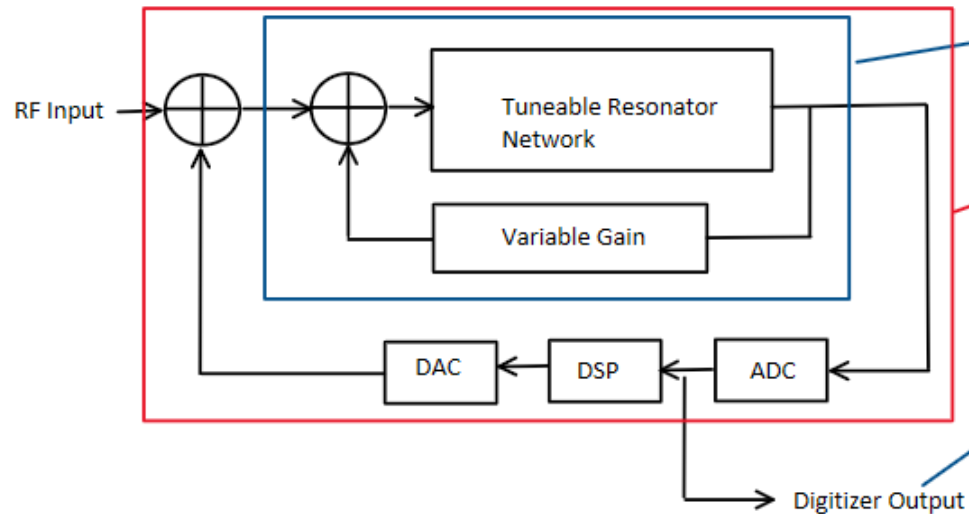
- Independent, orthogonal frequency and bandwidth tuning
- Capable of narrow bandwidth
- No insertion loss
- High out of band rejection, no regrowth
- The same circuit may form Butterworth, Chebyshev, or Gaussian responses
- Predictable performance
  - May be fully calibrated
  - Very stable
  - Passband shape and phase does not change with tuning
- Fast tuning, allows frequency hopping
- Easy to control



# Application Example

## Bandpass Delta Sigma – BDS

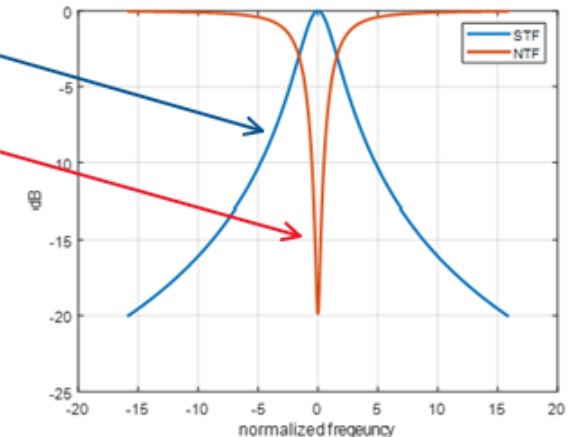
- A very effective combination of RF and DSP
- Eliminates noise within the BDS loop
  - RF noise
  - Quantization noise and sample/hold jitter
- Requires a high Q pole
- Must be frequency agile
- The pole Q may be increased/decreased for antialiasing



Anlotek pole forms a *single* resonator

BDS loop reduces quantization noise:  
Can scale to accommodate larger interfering tones without losing signal of interest in noise

Using the DSP native to the radio can further refine filtering of the digitized desired signal to meet all filtering specifications



- Without quantization noise a very low RF signal may be discerned even while scaling the ADC for very strong interference

# Application Example

## Bandpass Delta Sigma for Direct Conversion

Signal to Noise and Quantization

N = Number of Bits  
OSR = Oversampling Ratio

$$\text{SNR} = 6.02N + 1.76\text{dB} + 30\log(\text{OSR})$$

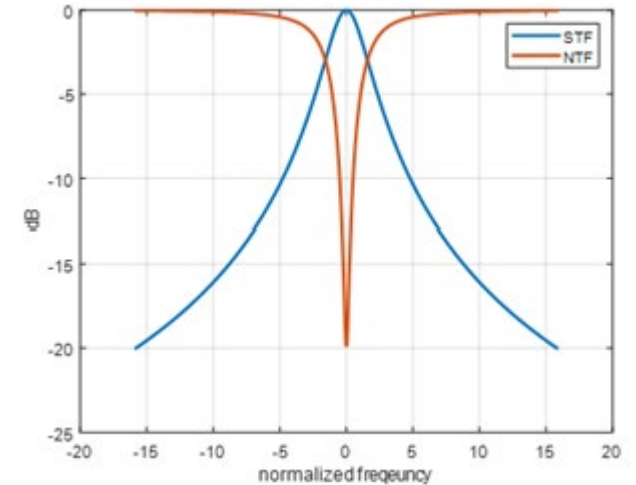
Using the ATK with direct conversion and proper antialiasing:

- OSR is the oversampling ratio of the filter or pole bandwidth
- OSR becomes the dominant factor
- N may be reduced

Essentially *each doubling of OSR is equivalent to 1.5 bits of resolution*

Choose the advantage:

- ADC scaling allows close in interference without saturation – small signal still discerned
- Reduced number of bits greatly simplifies digital processing





# Application Example

## Advantages of Anlotek's Bandpass Delta Sigma

- Usable at higher RF frequencies
  - Without downconversion
  - Only tunable pole and sample and hold need be at RF
  - Oversampling is occurring with respect to filter or pole bandwidth
- Lowers requirement for ADC resolution and clock frequency
- Allows a tradeoff between higher SNR performance and lower CPU needs
  - Superior link budget or
  - Better battery life and lower power consumption, or
  - More channels for a given CPU resource

# Application Example

## Considerations

- Only Anlotek's circuit:
  - A frequency tuneable circuit with sufficiently high Q
  - May be rapidly tuned to a new frequency for hopping
  - Has adjustable Q for bandwidth shaping and tight antialiasing
  - May be configured as a multipole filter of various types
  - The resonator can be of any type including:
    - *fixed SAWs and BAWs*
    - *Low Q IC based resonators*
- Enables:
  - Very flexible Software Defined Radio
  - *At least 10dB of additional Dynamic Range in hostile environments*
  - Very efficient and cost-effective radios for BT, IoT, (etc.) with great battery life

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## Conclusions

- Anlotek has found the solution for a tuneable RF bandpass filter
  - Very well-behaved filter characteristics
  - Independent tuning of  $F_c$  and bandwidth
  - May be rapidly tuned to a new frequency for hopping
  - Frequency range is entirely dependent upon the target technology
- Anlotek's Enhanced Bandpass Delta Sigma
  - Is not frequency constrained
  - Provides an effective increase in dynamic range
  - Allows for a decrease in quantization bits with oversampling
- Enables:
  - Very flexible Software Defined Radio
  - At least 10dB of additional Dynamic Range in hostile environments
  - Very efficient and cost-effective radios for BT, IoT, (etc.) with great battery life

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