

LOCAL OSCILLATOR FOR RADIO TELESCOPE WITH VERY FINE FREQUENCY TUNING

E.A.Alekseev,
Institute of Radio Astronomy
NAS of Ukraine

Heterodyne receivers as principal solution of radio astronomy

- Transformation of input signal to the frequency range of spectrum analyzer (usually multi step frequency transformation)
- Corrections of Doppler shift because of the Earth's motion

One of the important parts of heterodyne receiver is local oscillator

Local oscillator is frequency synthesizer

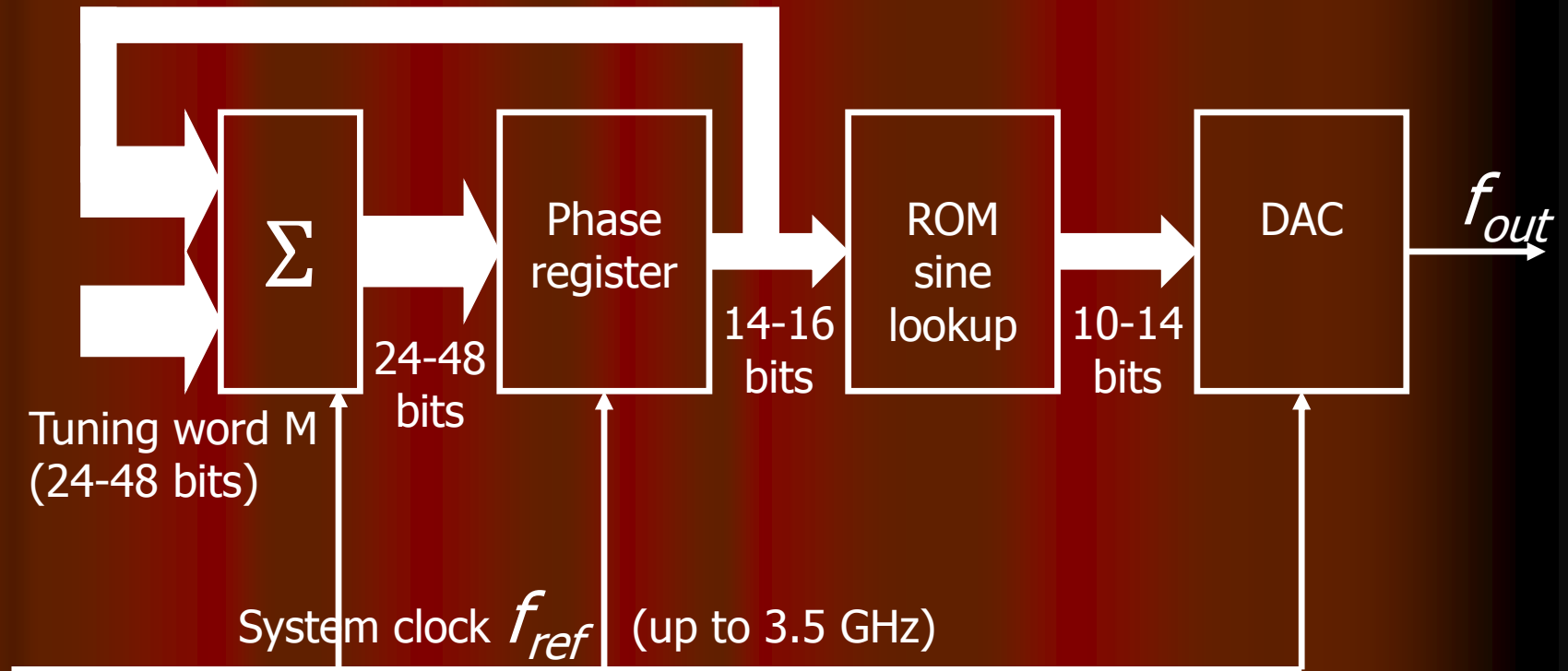
- Corrections of Doppler shift because of the Earth's motion requires very fine frequency tuning of local oscillator (~ 0.0001 MHz with 0.001 MHz resolution or $\Delta f/f \sim 3 \times 10^{-8}$)
- It is **VERY DIFFICULT** to construct PLL synthesizer with such fine frequency tuning

Last years there appeared
DIRECT DIGITAL SYNTHESIZERS
with essential advantages

Outline

- What is it DDS?
- Advantages and disadvantages of DDS
- Narrow-band output spectrum of DDS: is it acceptable for high-resolution spectroscopy?
- Improvement of DDS spectral purity
- Upconverter as local oscillator with very fine frequency tuning
- Conclusions

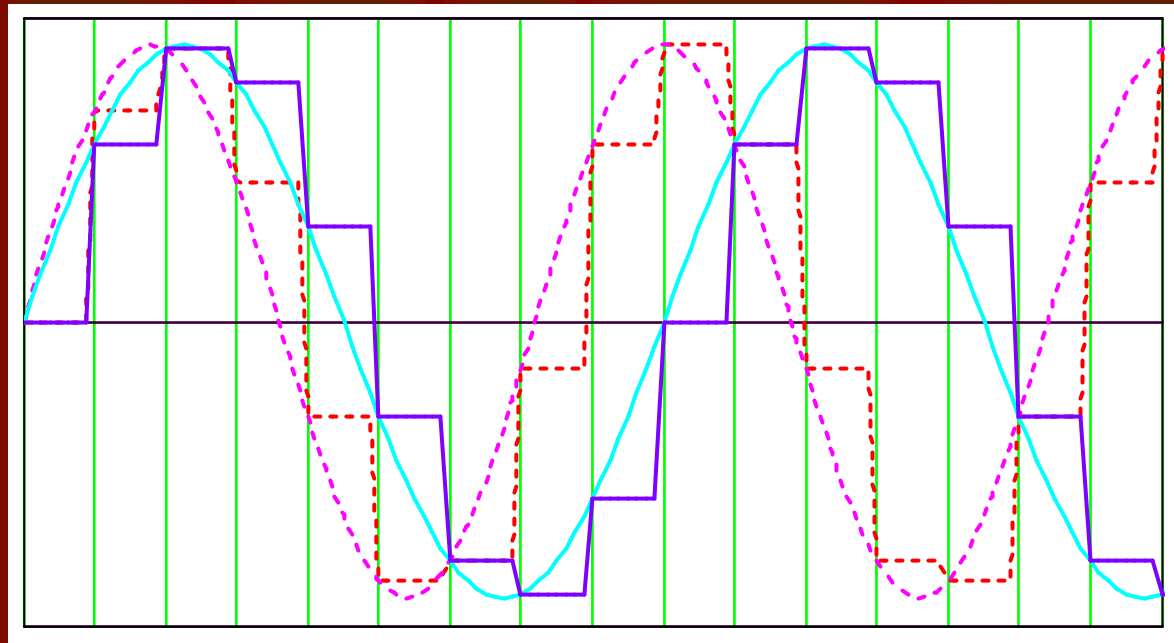
What is it DDS?



DDS output without filtering

For AD9852 $f_{out} = M \times 300\text{MHz}/2^{48}$ $\Delta f = 0.000001... \text{ Hz (!)}$

Amplitude a.u.



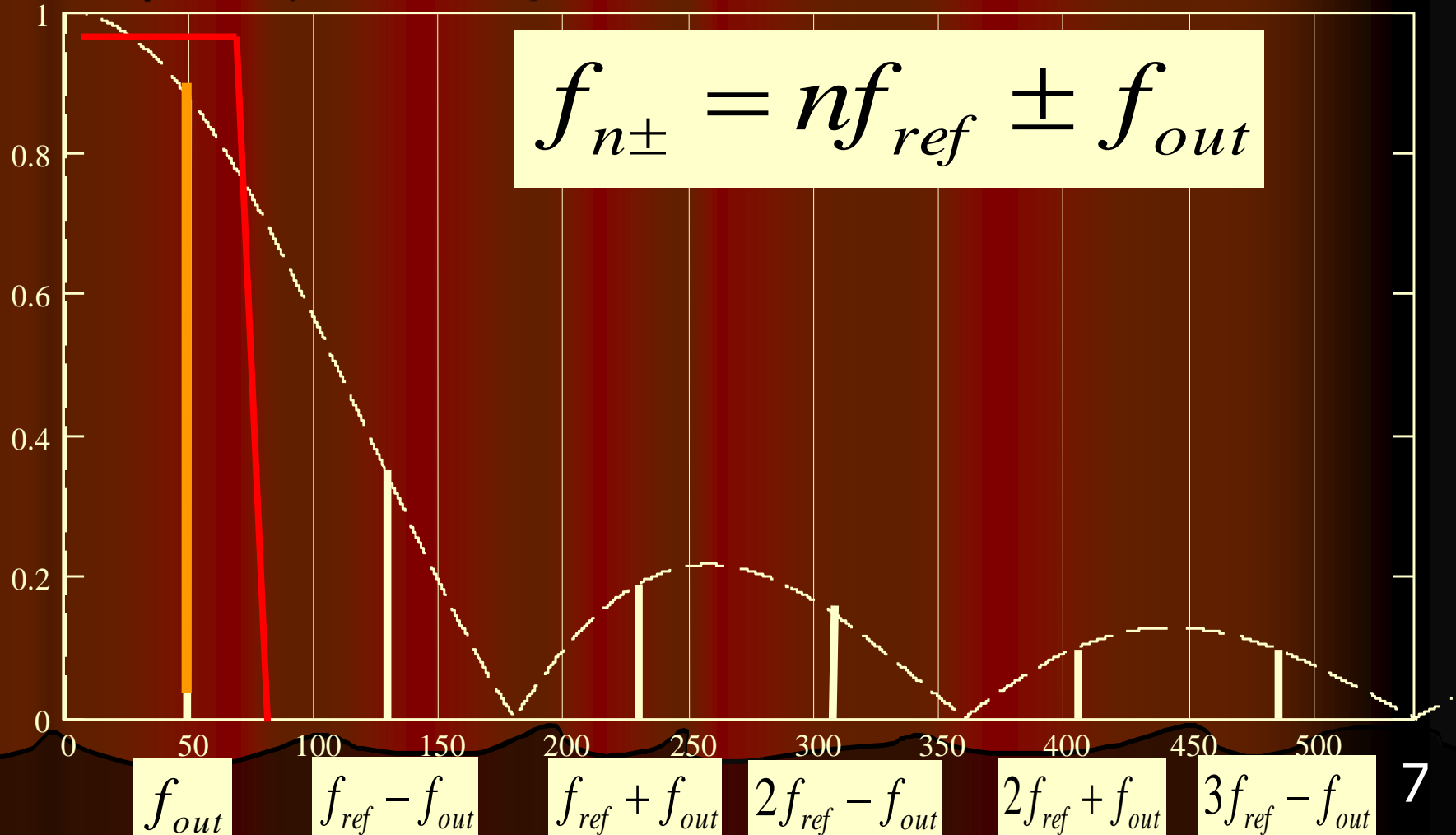
Time, a.u.

Output spectrum of AD9850

$$f_{out} = 50\text{MHz}$$

$$f_{ref} = 180\text{MHz}$$

Amplitude (relative units)

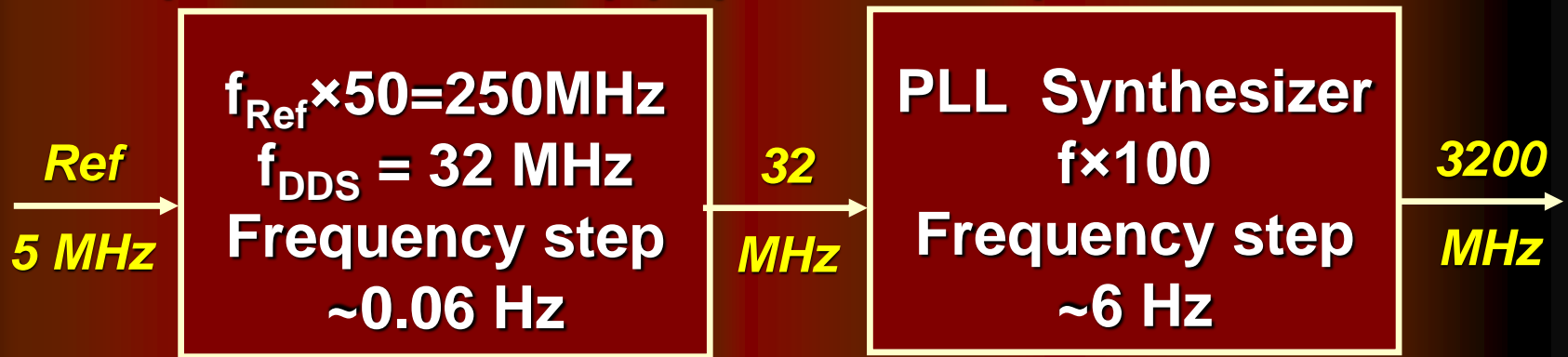


Advantages of DDS

- Extremely high frequency resolution (down to 10^{-6} Hz)
- Very fast frequency switching (10 ns)
- Frequency switching with continues phase
- Possibility of FM, swept-FM, ...
- Possibility of fixed phase shift between different synthesizers
- Etc.

3200 MHz local oscillator based on the DDS: preliminary solution

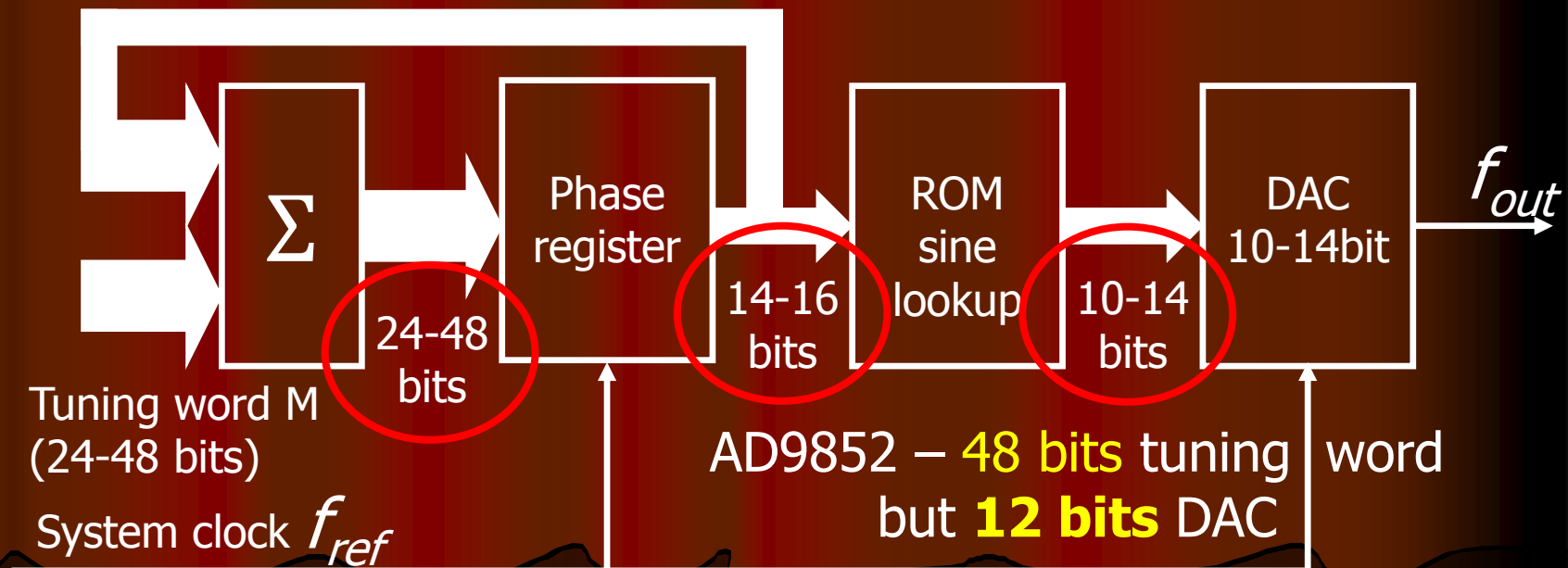
- We supposed that because of not too high frequency multiplication factor (100) it will be possible to apply the simplest solution :



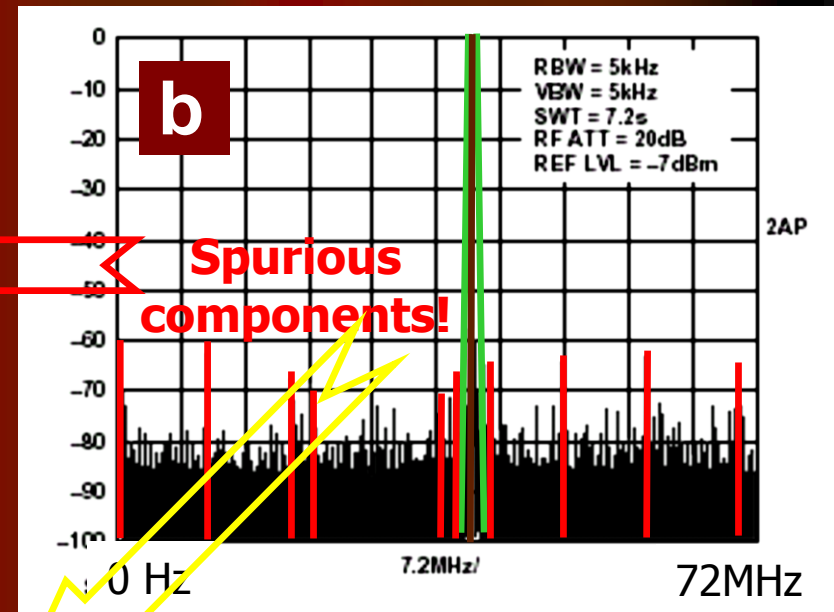
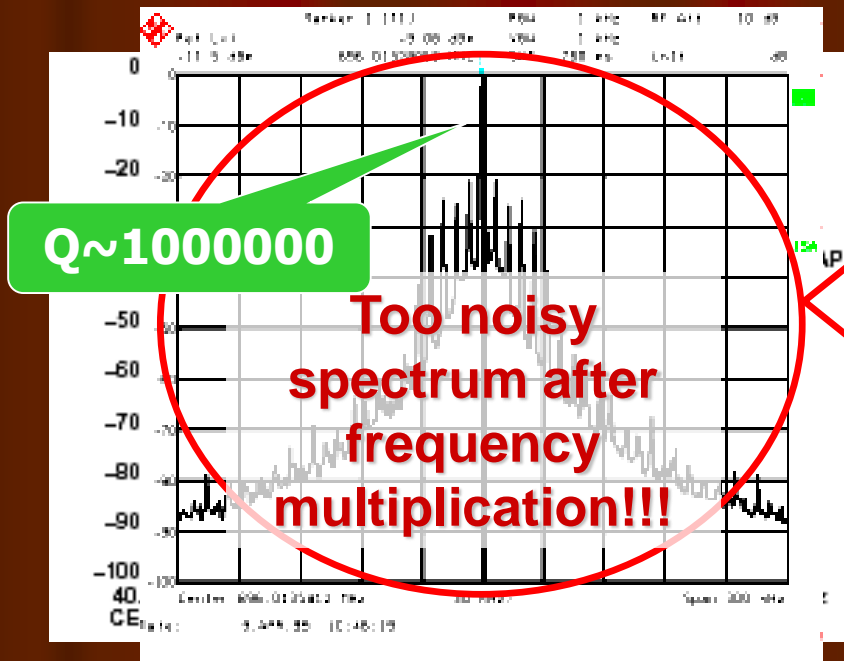
- But the simplest solution gives **TOO NOISY** spectrum

Disadvantages of DDS

- Very sensitive to quality of reference signal
- The highest operating frequency <1200 MHz => necessary frequency multiplication
- **Spurious components in output spectrum**



Narrow & wide - band DDS spectrum (AD9851)

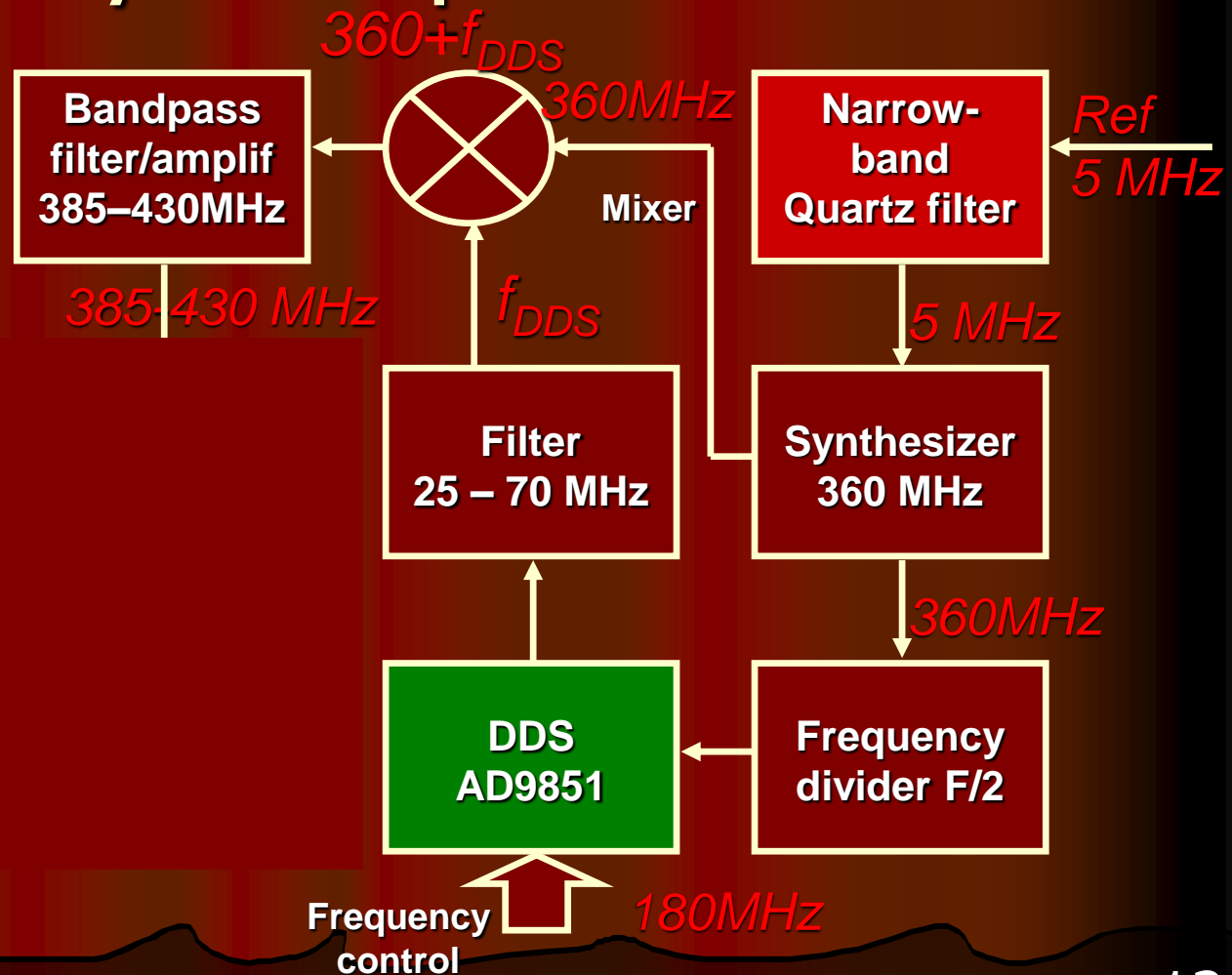


a) $BW = \pm 0,1 \text{ MГц}$

b) $BW = 0 - 72 \text{ MГц}$

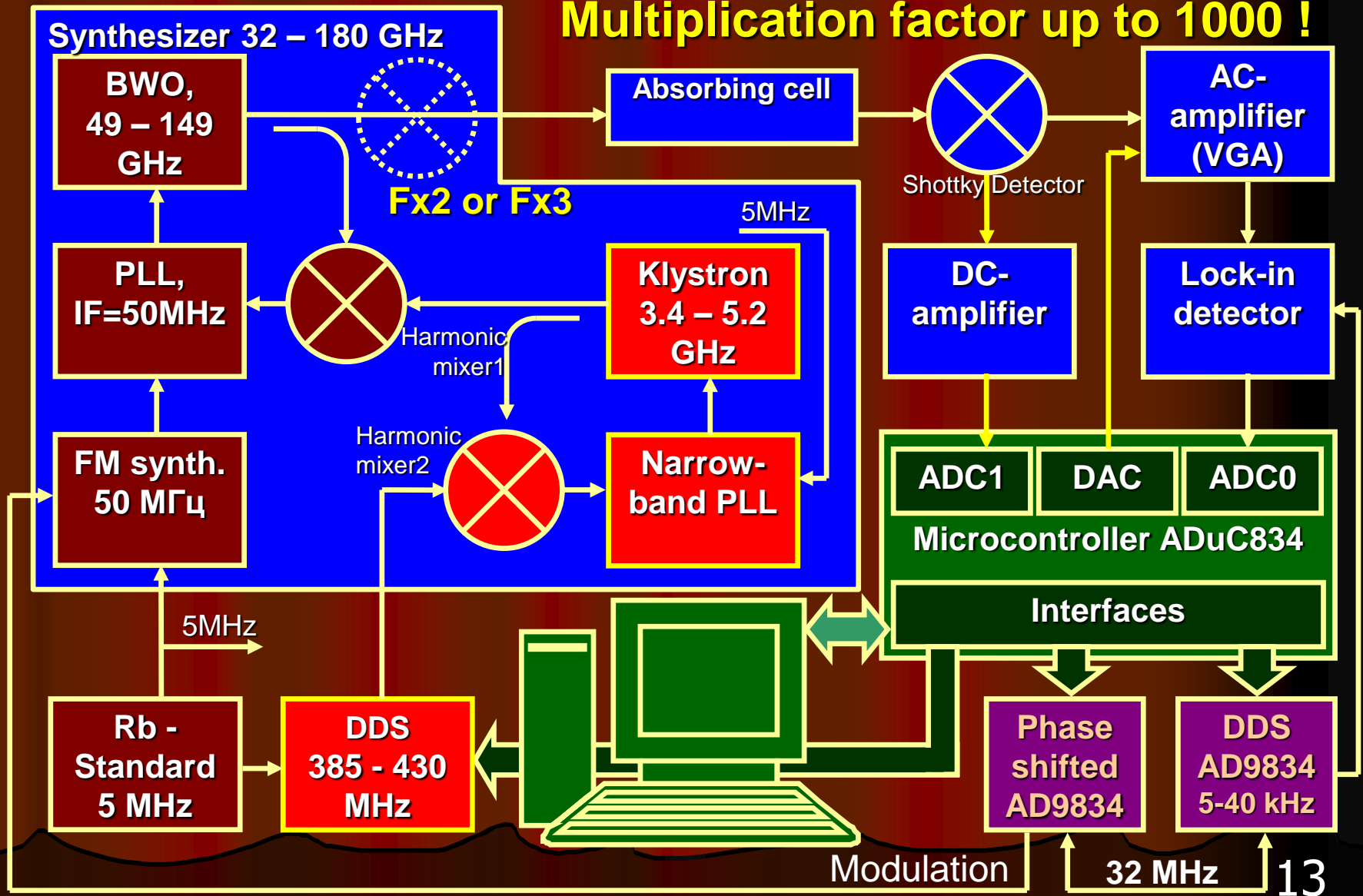
Narrow-band adaptive filtering or/and minimal factor of frequency multiplication!

Upconverter: reduction of frequency multiplication factor



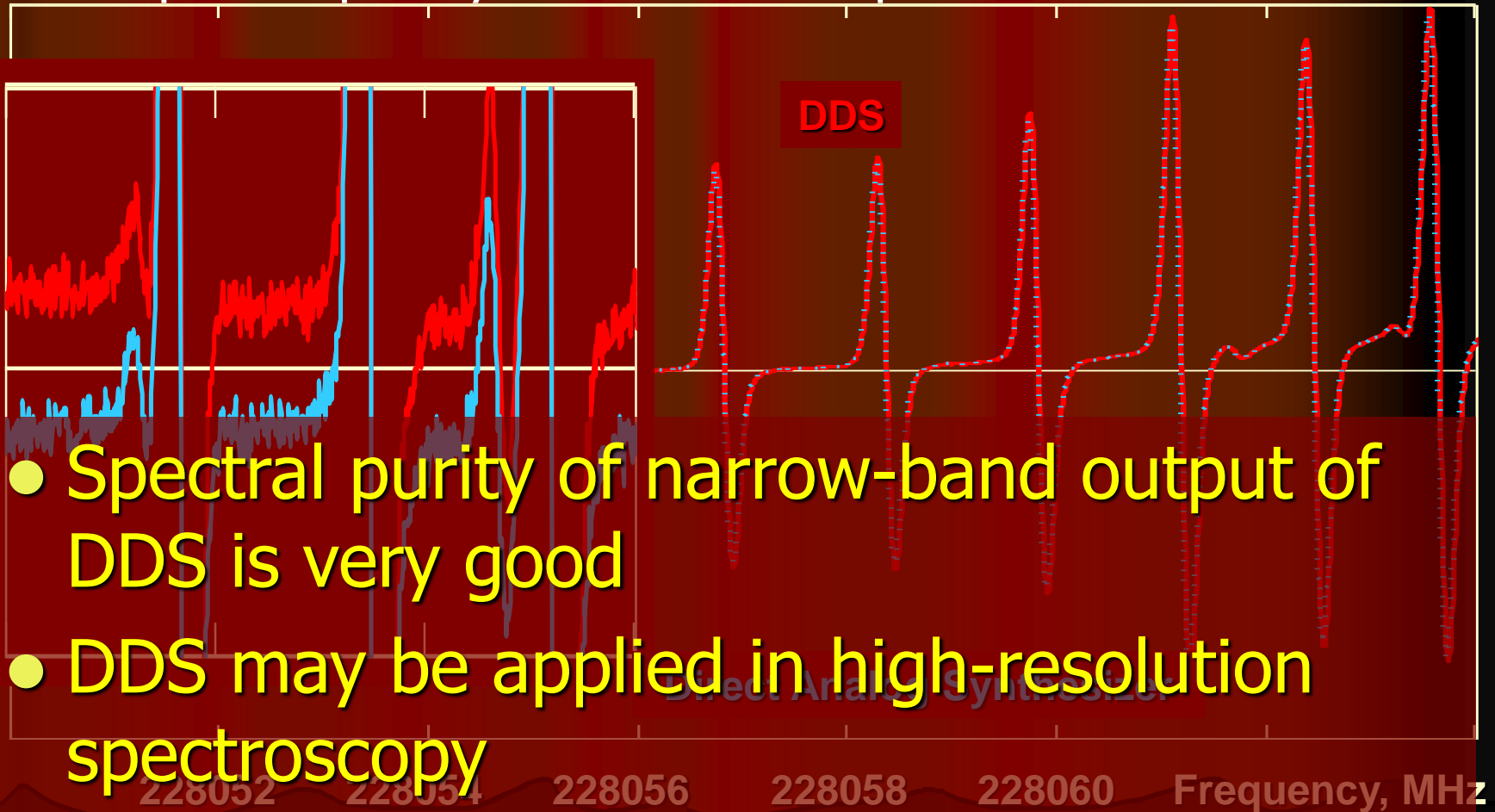
MW spectrometer in Kharkov

Multiplication factor up to 1000 !

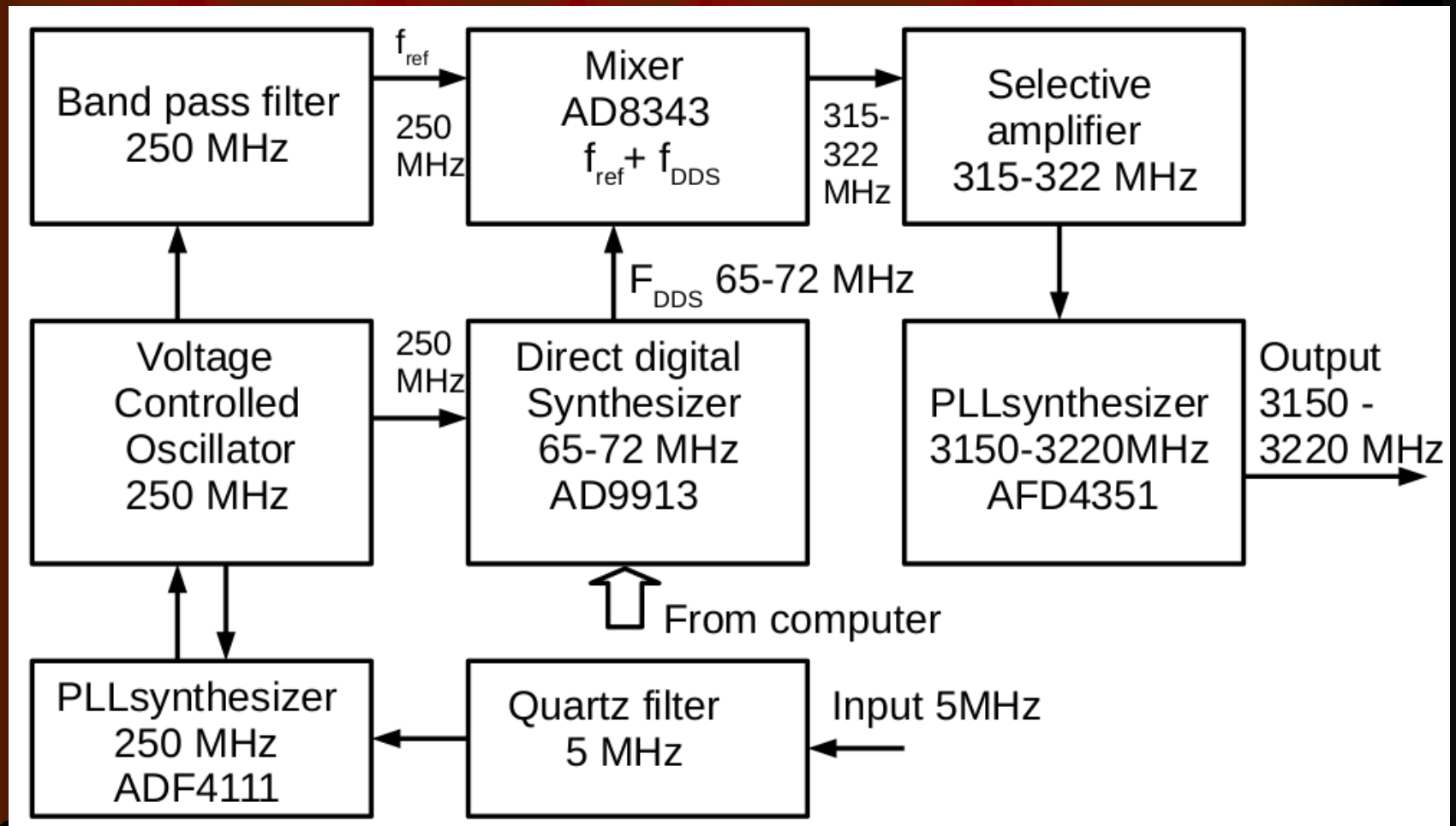


Portion of CF_3CH_3 spectrum

Output frequency of DDS is multiplied about **600** times!



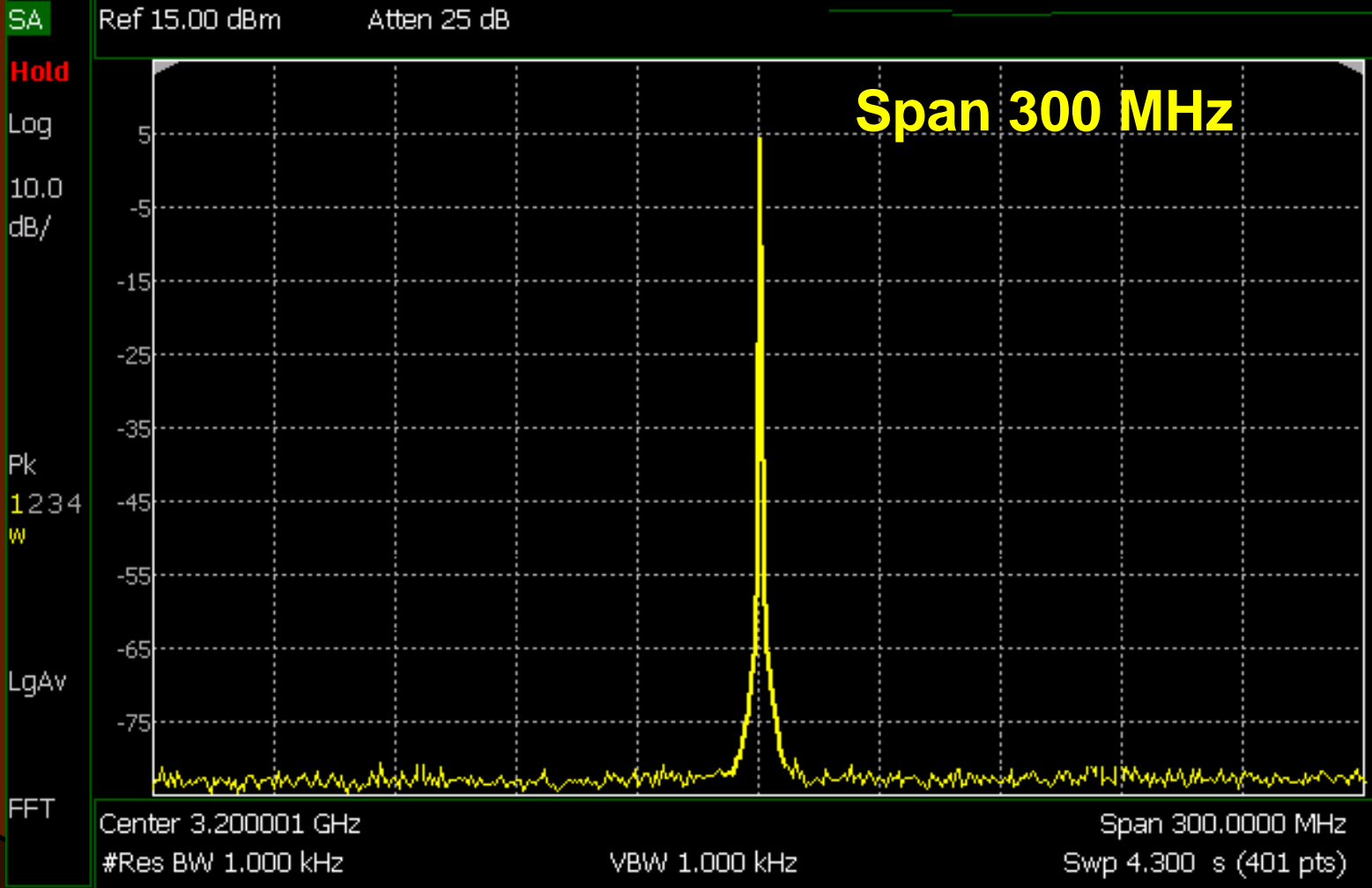
3200 MHz local oscillator based on the DDS with upconverter



Output spectrum of LO 3200MHz

Keysight Technologies: N9951A, SN: MY56161048

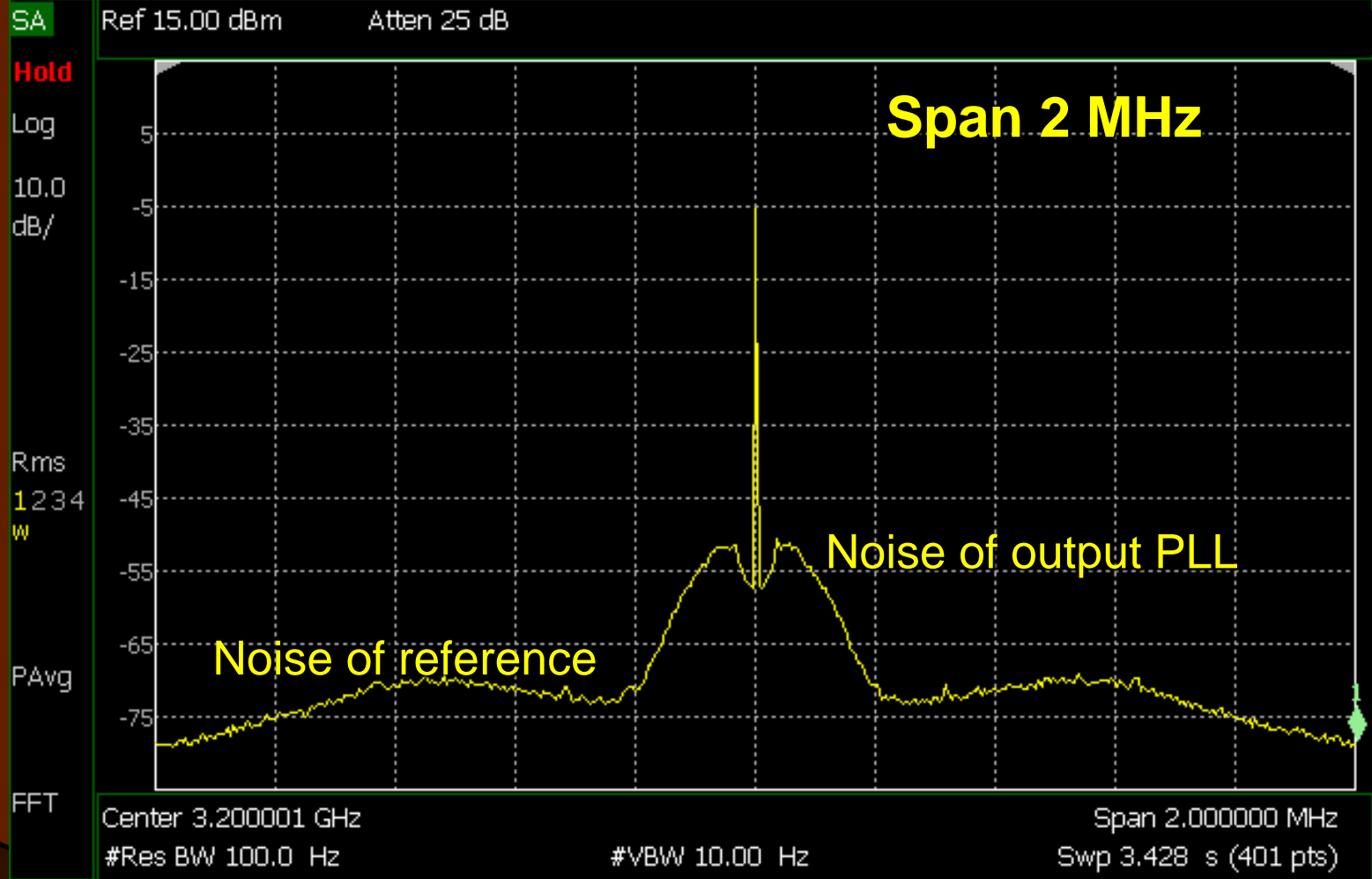
Fri, 08 Feb 2019 11:58



Output spectrum of LO 3200MHz

Keysight Technologies: N9951A, SN: MY56161048

Fri, 08 Feb 2019 11:50



Main features of 3200 MHz local oscillator

- Frequency range: 3150 – 3220 MHz
- Principal limitation of frequency tuning is **~0.6 Hz** (it corresponds **$\Delta f/f \sim 2 \times 10^{-10}$**)
- Because of 0.001 MHz resolution of spectrum analyser minimal frequency step is set by software at 0.0001 MHz
- Phase noise with 10 kHz offset -82 dBc/Hz
- Phase noise with 1 MHz offset -97 dBc/Hz

Conclusions

Application of DDS allows to obtain:

- Very fine frequency tuning down to $\Delta f/f \sim 2 \times 10^{-10}$

Under conditions:

- High quality reference signal
- Minimal frequency multiplication factor
- Narrow-band adaptive filtration

Thank you for your attention!