Tu01E

Advances in Microwave Synthesizer Technology

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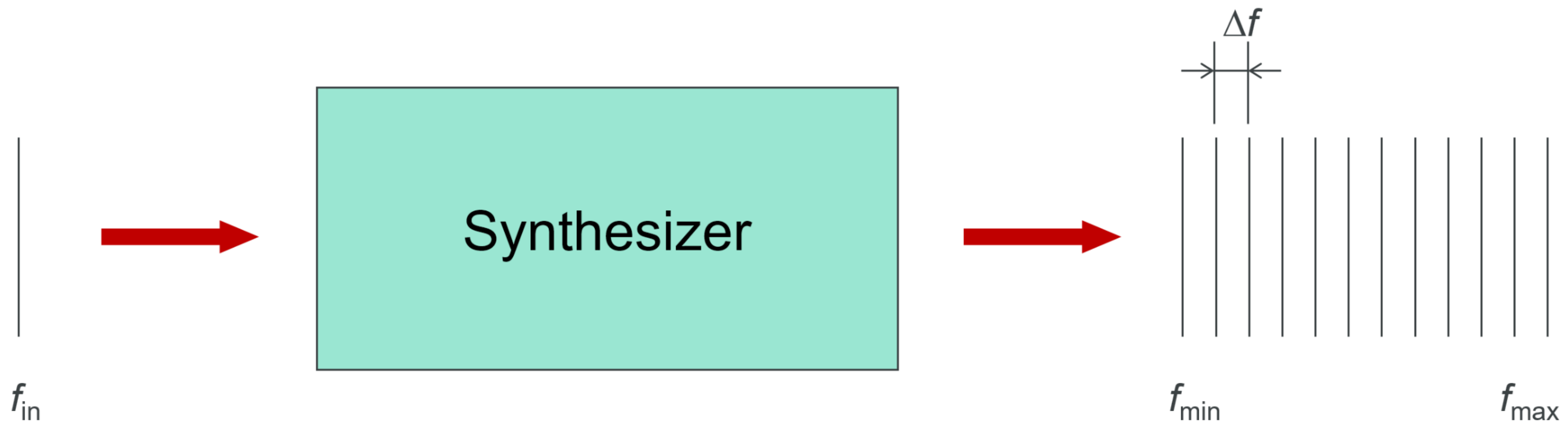
Agenda

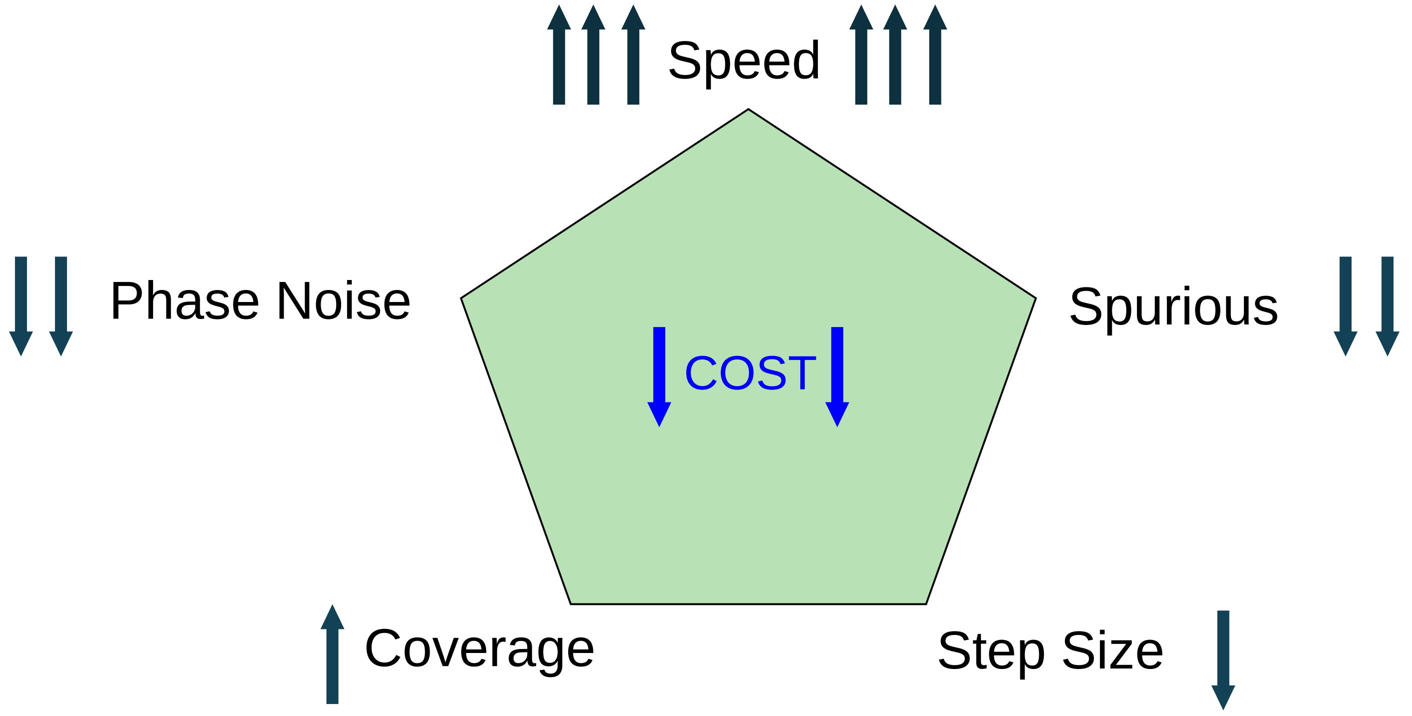
- Frequency Synthesizers Market
- Market Drivers
- Market Demands
- Main Architectures
- Design Examples
- Future Projections

Frequency Synthesizer Definition

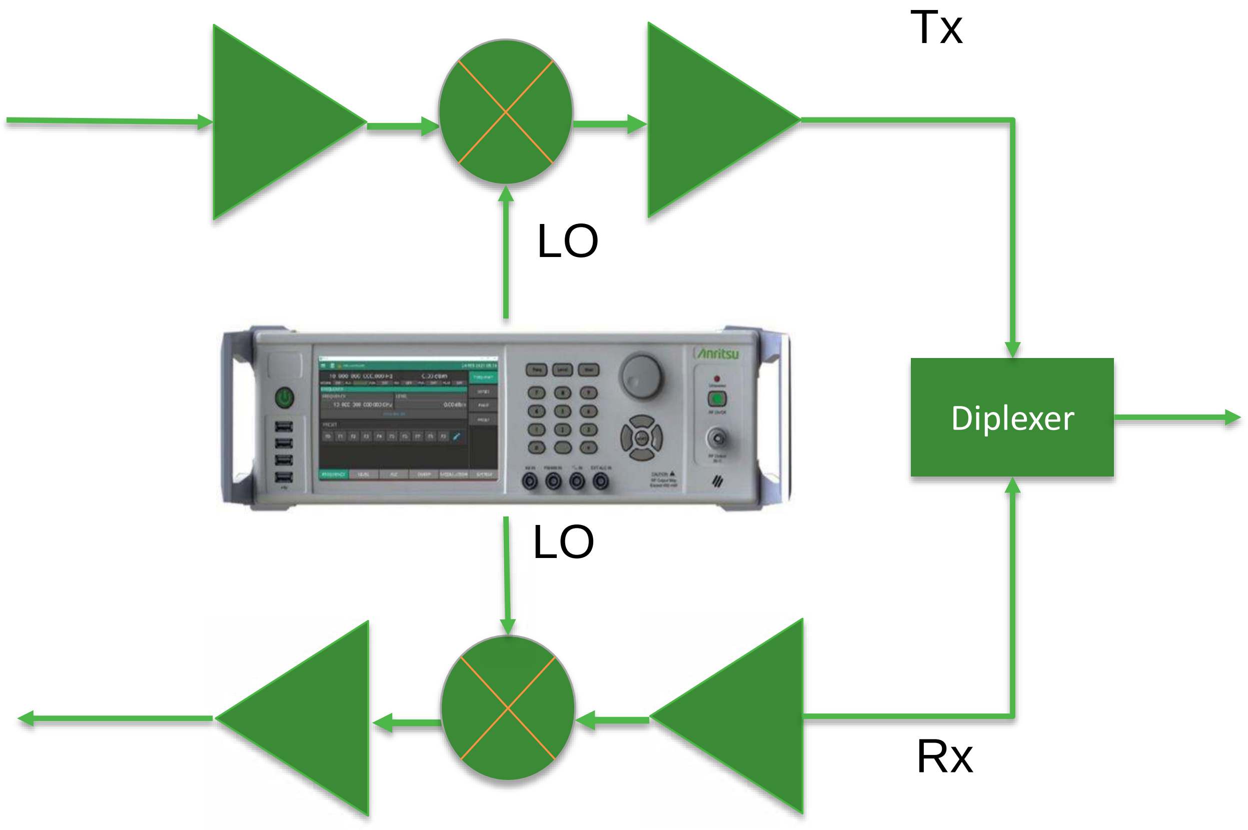


A frequency synthesizer is an electronic device that translates one (or more) reference frequencies to a number of output frequencies

Main Characteristics

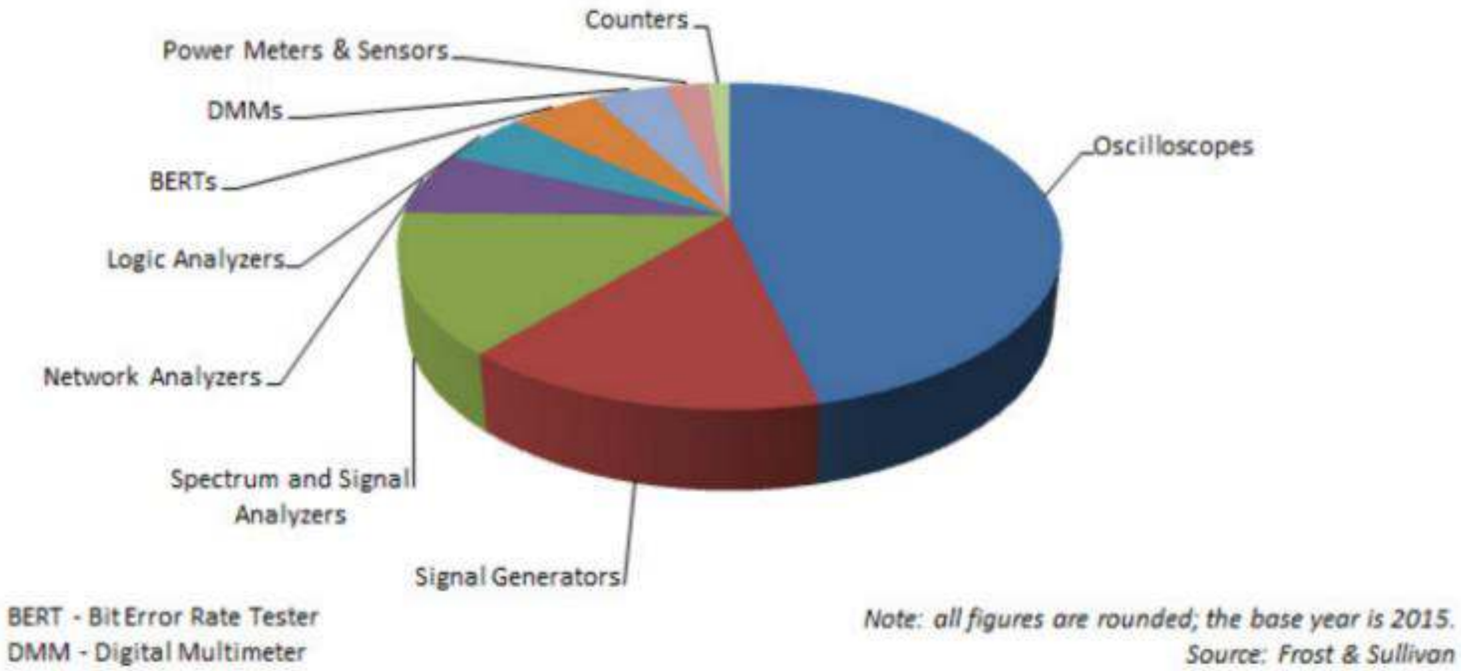


Frequency Synthesizers



The frequency synthesizer is a key component of virtually any RF/microwave test-and-measurement, communication, and monitoring systems

Frequency Synthesizers Market



According to Frost & Sullivan signal generators is one of the fastest growing segments in the global test-and-measurement market with an annual growth rate about 7%

Market Drivers

- Wireless communications
- Aerospace and defense
- Automotive industries
- New technologies such as 6G

Market Demands

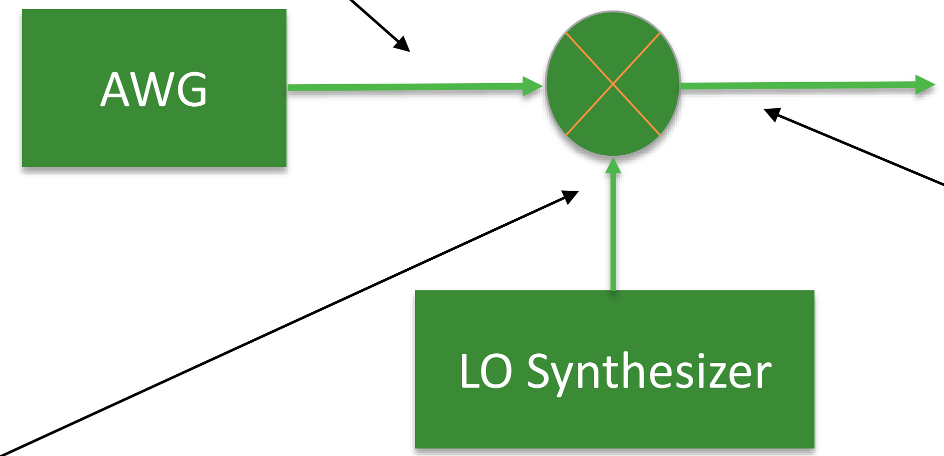
- The principal driver behind the 6G technology is ever-increasing need for more capacity and higher data rates in wireless networks
- Due to the heavy use of existing frequency bands, there is a strong interest to use higher frequencies to enable more bandwidth
- This is generating the interest to move to beyond 100 GHz frequencies and to the sub-THz domain

Market Demands

- Aside from the frequency coverage, phase noise remains one of the most critical parameters that impose the ultimate limit in the system's ability to resolve signals of small amplitude
- Furthermore, today the industry demands more complex waveforms to transmit more information over available frequency bands

6G Challenges

Complex waveforms to transmit more information over available frequency bands



sub-THz frequencies to enable more bandwidth

Starting with the lowest possible phase noise is essential due to high multiplication factors in the LO chain

Synthesizer Trends

- Higher operating frequencies
- Lower phase noise
- Complex modulation capabilities

Synthesizer Architectures

Direct Analog

Direct Digital

Indirect (PLL)

Synthesizer characteristics depend heavily on a particular architecture that can be classified into a few main groups, namely, direct analog, direct digital and indirect schemes

Synthesizer Architectures

Direct Analog

Direct Digital

The direct architectures are intended to create output signals directly from the available base frequencies either by manipulating and combining them in the frequency domain (direct analog synthesis) or by constructing the output waveform in the time domain (direct digital synthesis)

Synthesizer Architectures

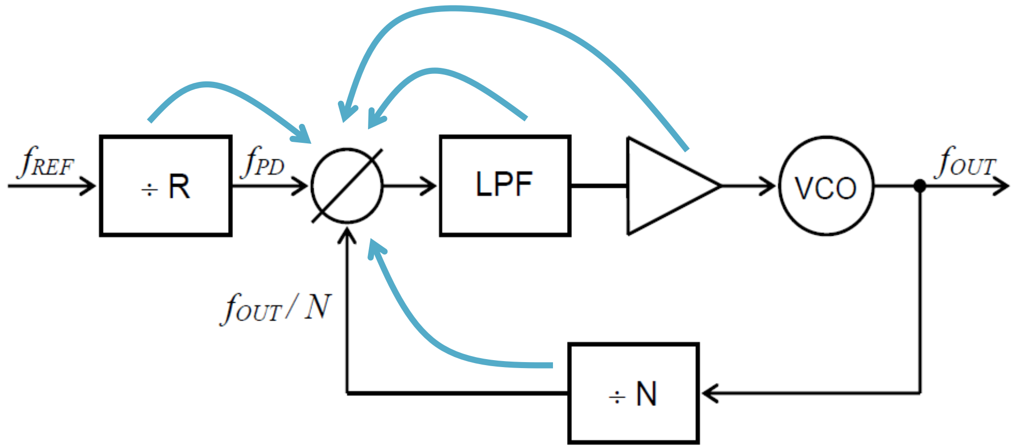
Indirect (PLL)

The indirect methods assume that the output signal is regenerated inside the synthesizer in such a manner that the output frequency relates to the input reference signal

Synthesizer Architectures

Direct Analog	Low phase noise, fast switching speed
Direct Digital	Fine resolution, fast switching speed
Indirect (PLL)	Lower complexity and lower cost

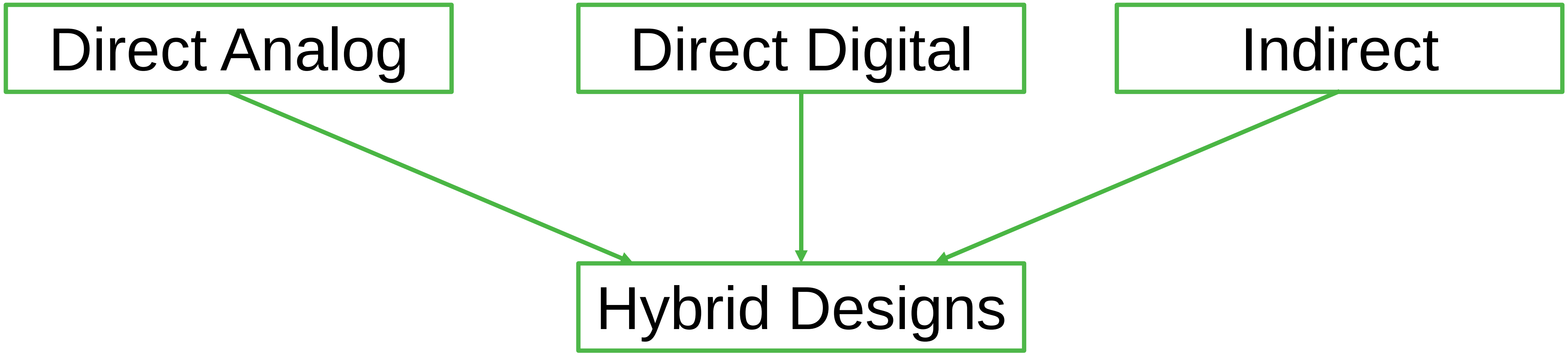
PLL Synthesizers



$$\mathcal{L}_{PLL} = \mathcal{L}_{\Sigma PD} + 20\log N$$

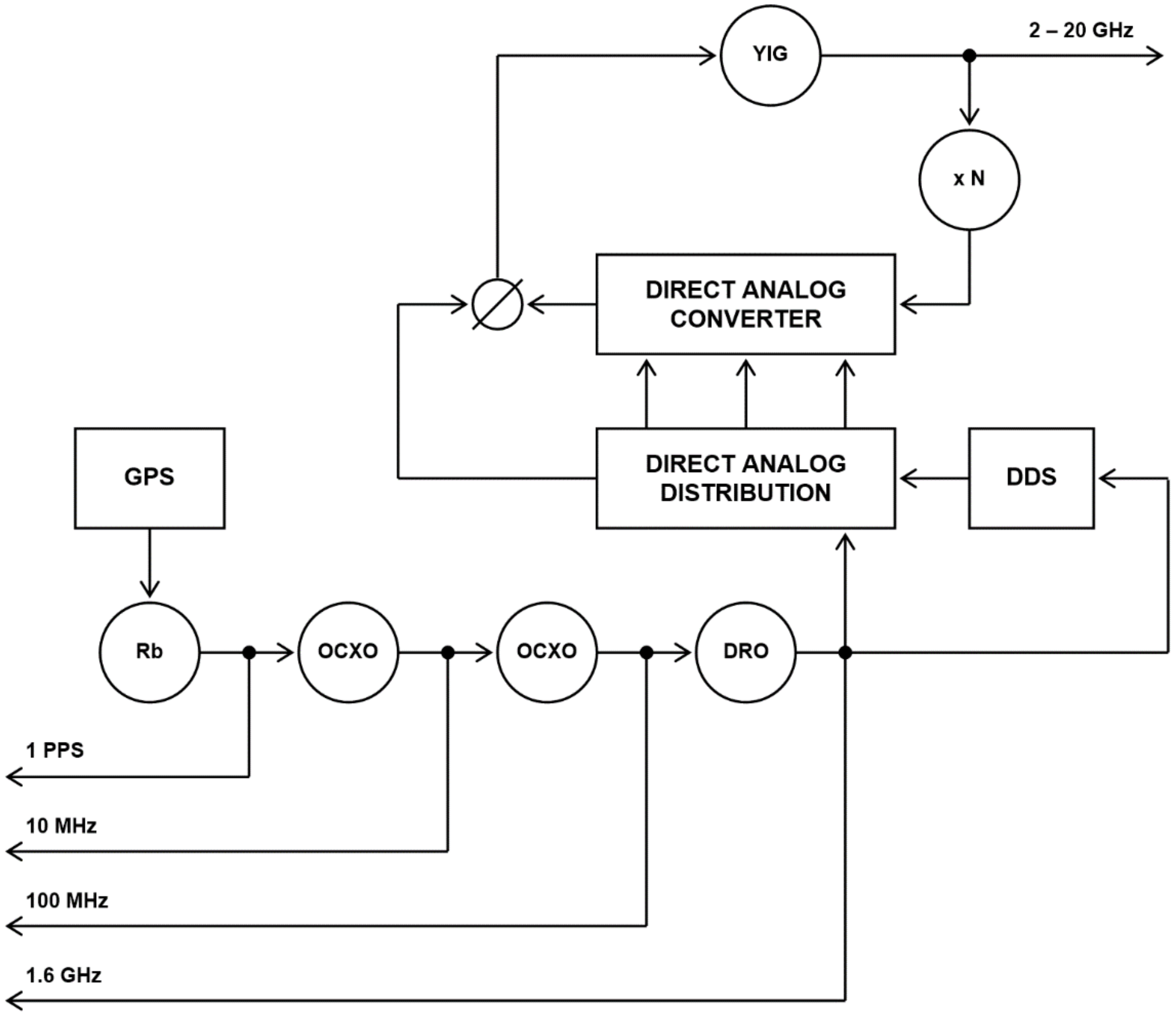
Phase noise generated by PLL components is degraded by large division ratios required to provide a high-frequency output with a fine resolution

Synthesizer Architectures



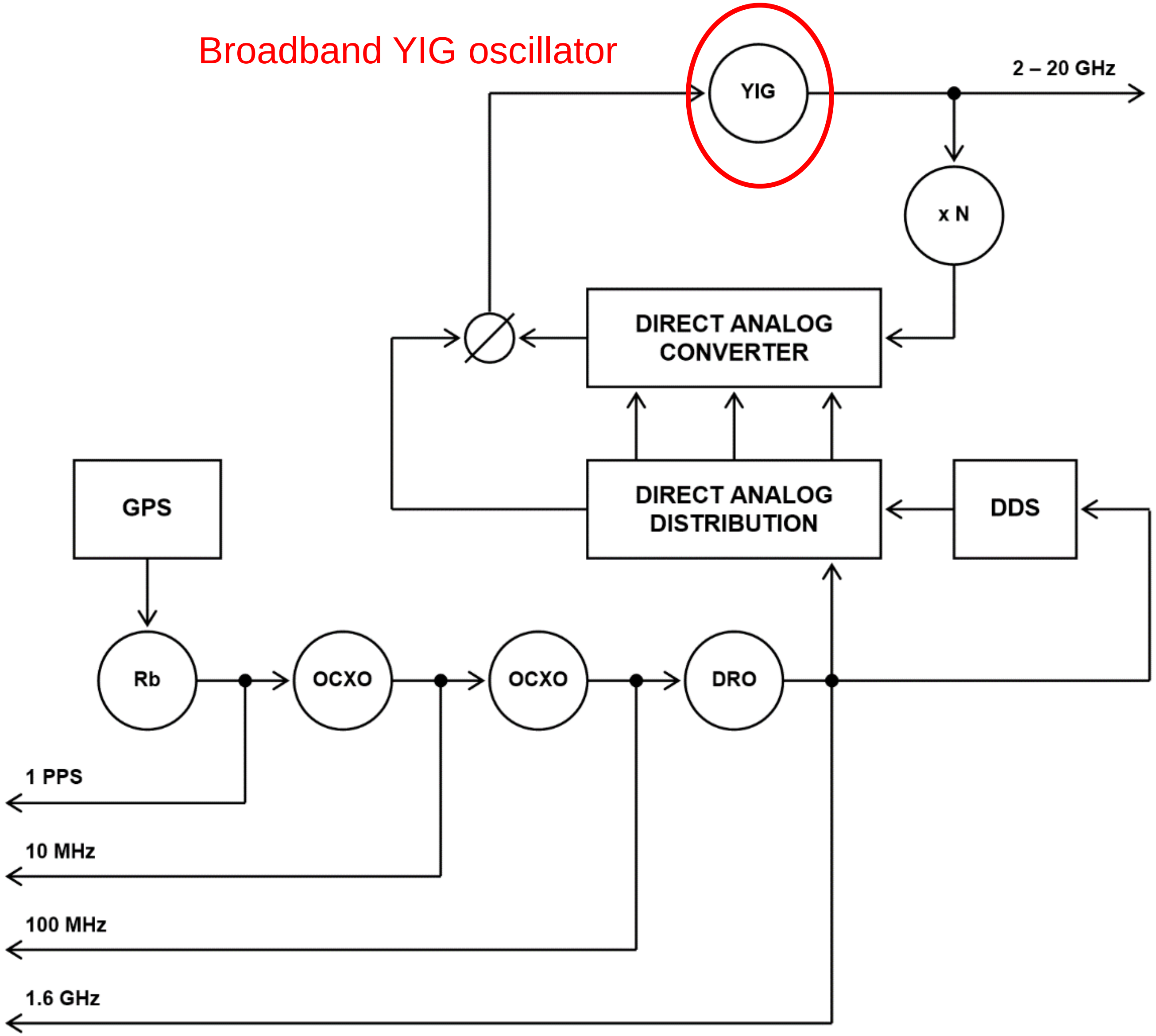
A practical synthesizer is usually a hybrid design that combines various techniques to achieve specific design goals

Hybrid Design Example

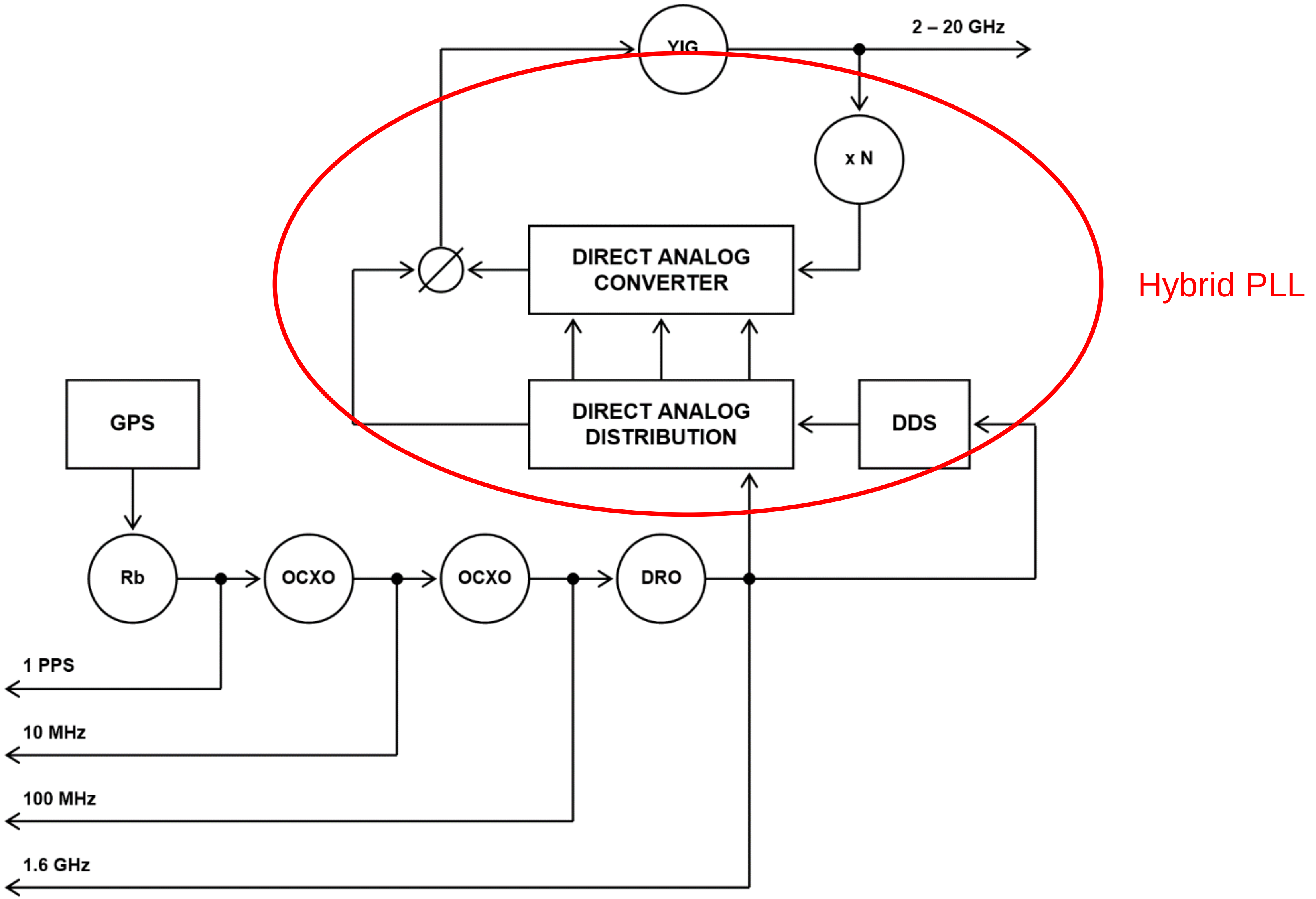


Hybrid Design Example

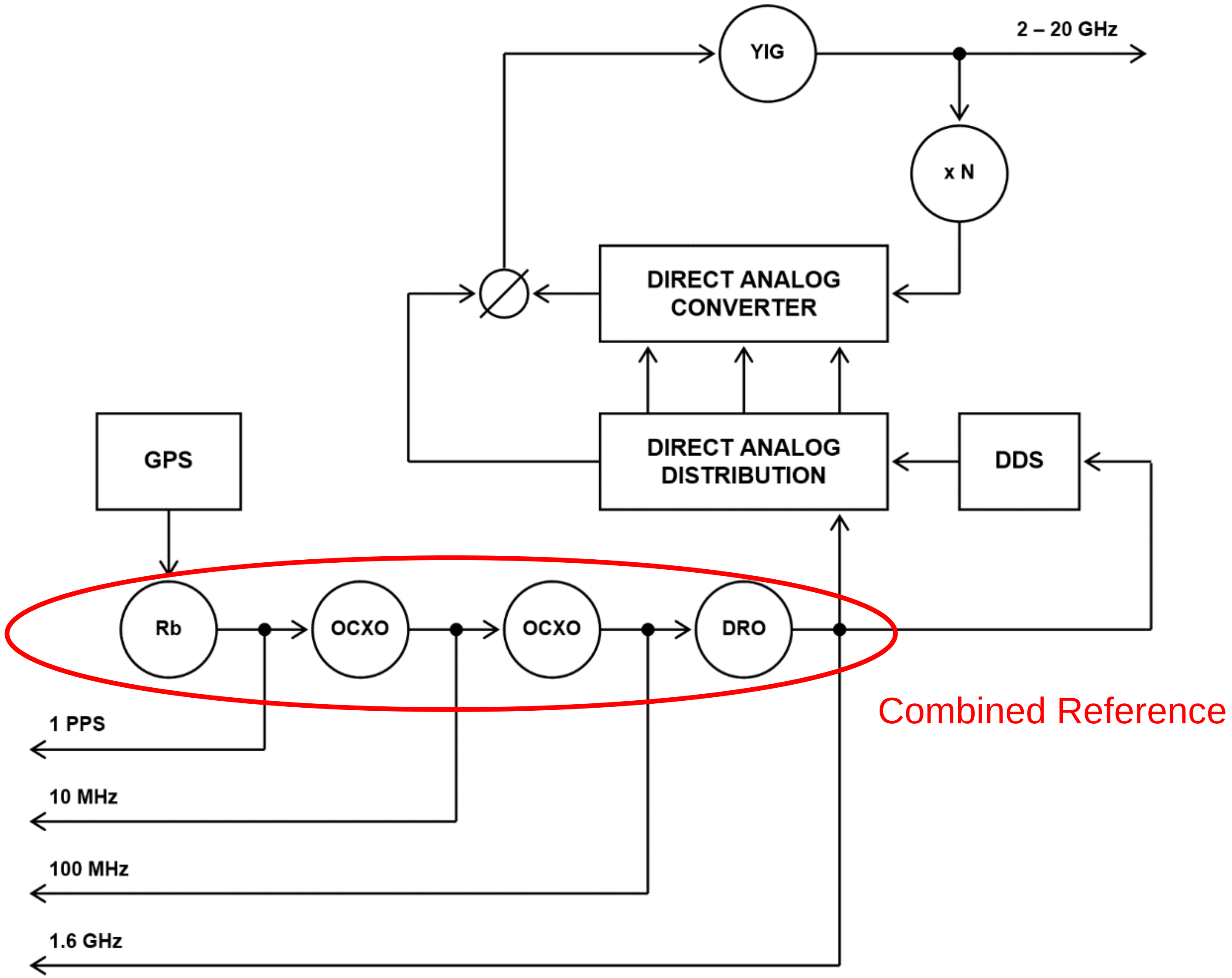
Broadband YIG oscillator



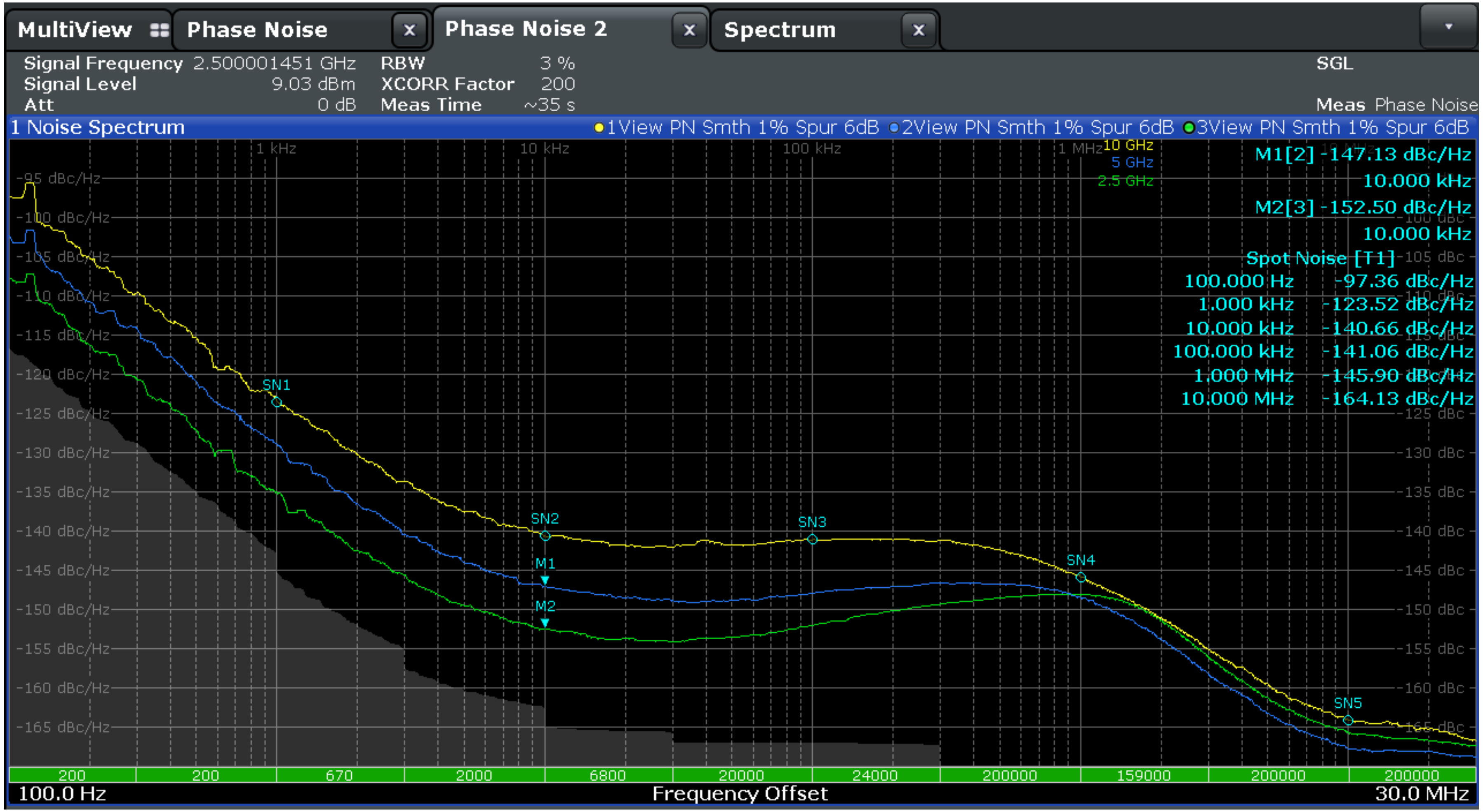
Hybrid Design Example



Hybrid Design Example

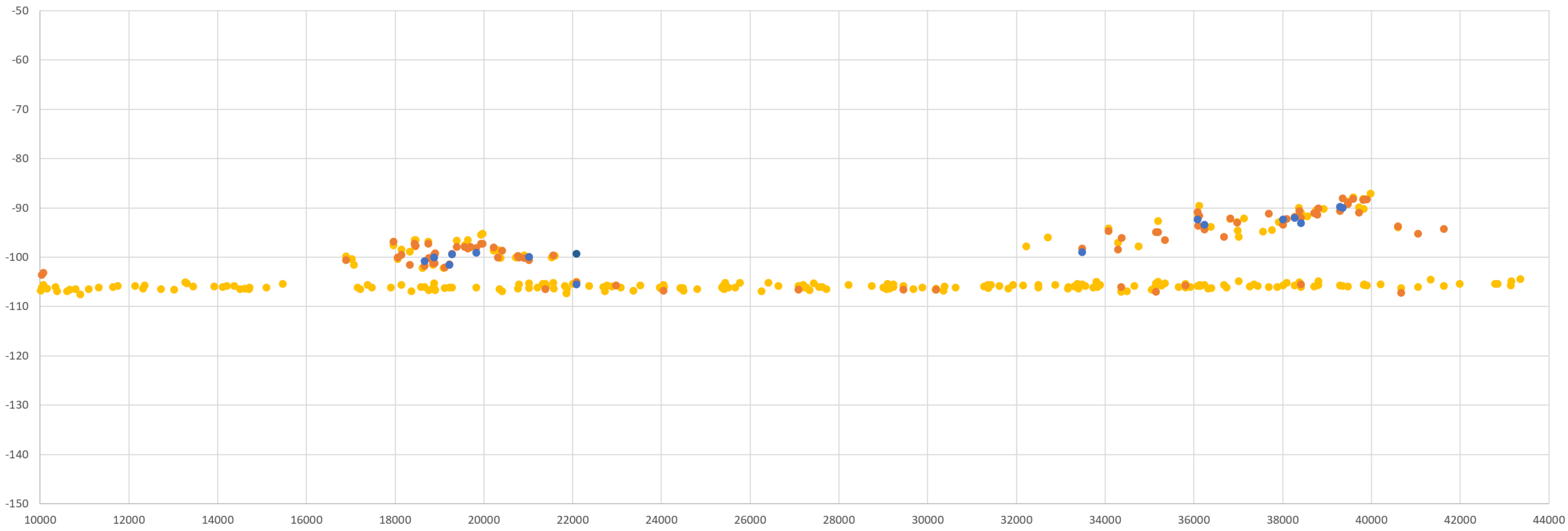


Phase Noise Performance

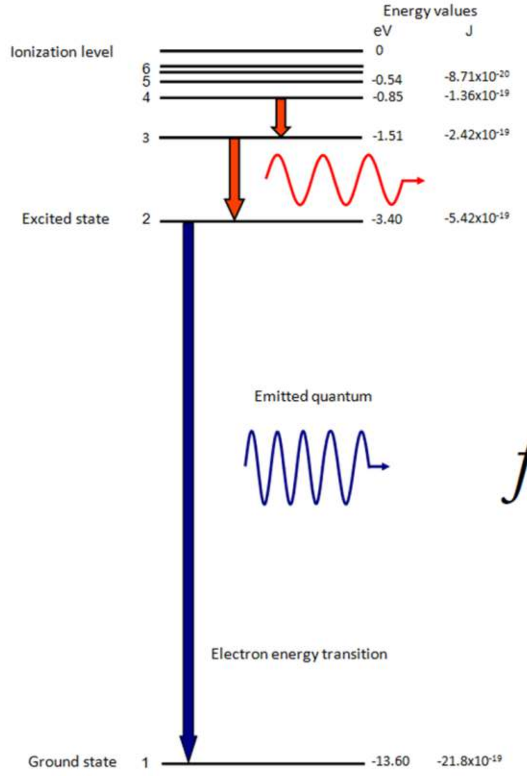


-140 dBc/Hz at 10 GHz Output and 10 kHz offset

Spurious Performance



Atomic Grade Stability



$$f = \frac{\Delta E}{h}$$

Built-in rubidium clock offers an atomic-grade stability

Conclusions

- The test-and-measurement synthesizer market is estimated at $300M with an annual growth rate about 7%
- As of today, traditional indirect PLL architectures still dominate
- Phase noise of -140 dBc/Hz at 10 GHz output and 10 kHz offset for a 9 kHz to 43.5 GHz wideband synthesizer has been recently reported
- On the other hand, direct analog synthesis is the most advanced approach that demonstrates extremely fast switching speed and low phase noise

Conclusions

- However, future developments are associated with direct digital synthesis due to the rapid progress in solid-state technologies
- We expect new DDS working directly at microwave frequencies (tens of GHz) with reduced spurious content
- Furthermore, modern synthesizers are also expected to generate complex waveforms

Conclusions

- Arbitrary waveform generators are utilized to generate complex (essentially any arbitrarily defined) waveforms
- Similar to DDS technologies, the extension of AWG usable bandwidth to microwave frequencies is expected
- Such complex signals can be further up-converted to millimeter-wave and sub-THz frequencies targeting future communications systems such as 6G

Discussion