Современное состояние и пути развития синтезаторов частот СВЧ-диапазона

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Frequency Synthesizer Concept

- $F_{in}$
- $F_{min}$
- $F_{max}$
- $\Delta F$
- $t$

- Spur
- Phase Noise

Start: 5.975000 GHz
Stop: 6.025000 GHz
Res BW: 0 Hz
Vid BW: 0 Hz
Sweep: 0 s

-20 -10 0 -10 -20 -30 -40 -50 -60 -70 -80 dBm
Market Demands

- Speed
- Phase Noise
- Spurious
- Coverage
- Step Size
- COST
The time spent by the synthesizer transitioning between frequencies becomes increasingly valuable since it cannot be used for data processing.
Technical Solutions

- Direct Analog Synthesizers
- Direct Digital Synthesizers
- Indirect Synthesizers
Direct Analog Synthesizers

**Advantages:**
- Fast Tuning, Low Phase Noise

**Disadvantages:**
- High Spurious
- Limited Number of Output Frequencies
  (only 18 in this example)
Direct Analog Synthesizers

Disadvantages: High Complexity and Cost
Direct Digital Synthesizers

Advantages:
Fast Tuning, Very Fine Resolution

Disadvantages:
High Spurious, Limited Bandwidth

\[ F_{\text{OUT}} \leq F_{\text{CLK}} / 2 \]
DDS Bandwidth Extension

It Becomes too Complex!
Indirect (PLL) Synthesizers

Advantages: Small Step Size, Low Spurs, Low Cost
Disadvantages: Slower Speed, Higher Noise

\[ F_{\text{OUT}} = F_{\text{REF}} \times N \]
PLL Noise Sources

\[ F_{\text{REF}} \rightarrow :R \rightarrow \text{LPF} \rightarrow \text{VCO} \rightarrow F_{\text{OUT}} \]

\[ + 20 \log N \]

\[ \mathcal{L}_{\Sigma} \]

\[ \mathcal{L}_{\text{VCO}} \]
Noise Reduction Techniques

\[ F_{\text{OUT}} = 10 \, \text{GHz} \]
\[ F_{\text{RES}} = 1 \, \text{MHz} \]
\[ N = 10,000 \]
Degradation = 80 dB

- Multiloop schemes
- Fractional-N
- Using DDS

\[ 20 \log N \]
PLL Noise Reduction

- use low-noise VCO (such as YIG)
- reduce N
Advantages: Broadband, low phase noise, linear tuning
Disadvantages: Bulky, power hungry, expensive, SLOW!!!
VCO or YIG?

VCO

**Advantages:** Small, Cheap, FAST!!!

**Disadvantages:** Worse phase noise
Oscillator Phase Noise

\[ \mathcal{L} = 10 \log \left\{ \frac{GFkT}{2P} \left[ \left( \frac{f_0}{2Q} \right)^2 \times \frac{f_0}{f^3} + \left( \frac{f_0}{2Q} \right)^2 \times \frac{1}{f^2} + \frac{f_0}{f} + 1 \right] \right\} \]
Phase Noise Contribution

Phase Noise

Reference

VCO

YIG

PLL Noise Floor

\[ f_{\alpha} \quad \frac{f_0}{2Q_{YIG}} \quad \frac{f_0}{2Q_{VCO}} \]

Frequency Offset
VCO versus YIG

Phase Noise

Frequency Offset

$f_{YIG\ opt}$  $f_{VCO\ opt}$

VCO-based

YIG-based
VCO versus YIG

Phase Noise

PLL Noise Floor

Frequency Offset

\[ f_\alpha \]

\[ f_0/2Q_{\text{YIG}} \]

\[ f_0/2Q_{\text{VCO}} \]
VCO versus YIG

Phase Noise

PLL Noise Floor

$f_\alpha$

$f_0/2Q_{YIG}$

$f_0/2Q_{VCO}$

Frequency Offset
VCO versus YIG

Phase Noise

PLL Noise Floor

\[ f \quad \alpha \quad f_0 \quad /2Q_{YIG} \quad /2Q_{VCO} \]

Frequency Offset
VCO versus YIG

Phase Noise

PLL Noise Floor

Frequency Offset
Reference Phase Noise

OCXO: 100 MHz  -163 dBc/Hz at 10 kHz
10 GHz   -123 dBc/Hz at 10 kHz
2 GHz    -137 dBc/Hz at 10 kHz
Combined Reference

The best phase noise profile at any frequency offset

2 GHz: -137 dBc/Hz at 10 kHz and 100 kHz, -160 dBc/Hz at 1 MHz
Key Design Principles

- Using a very low-noise reference source
- Reducing PLL residual noise floor
- Extending the loop filter bandwidth
Common PLL Noise Reduction Techniques

- Multiloop schemes
- Fractional-N
- Using DDS
New Techniques

(12) United States Patent
Chenakin

(10) Patent No.: US 7,701,299 B2
(45) Date of Patent: Apr. 20, 2010

(54) LOW PHASE NOISE PLL SYNTHESIZER

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(73) Assignee: Phase Matrix, Inc., San Jose, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 3 U.S.C. 154(b) by 105 days.

(21) Appl. No.: 12/205,632

(22) Filed: Sep. 5, 2008

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Diagram of a low phase noise PLL synthesizer.
Conclusions and Future Projections

- High Performance & Very High Cost
  - Direct Analog
- Balanced Performance & Cost
  - Indirect PLL
  - YIG → VCO
- Low Cost & Low Performance
  - Single-loop PLL

Cost vs. Performance graph illustrating the trade-offs between cost and performance for different types of frequency synthesizers.
Quick Facts

- FSW-0010 0.1-10 GHz
- FSW-0020 0.2-20 GHz
- 0.001 Hz resolution
- 100 uSec switching
- Instrument-grade spectral purity
- Output power control
- AM, FM, PM, Pulse Modulation
Switching Speed

Switch Time @ 10.2 GHz

SERIAL NUMBER 10011

17% 71.1 μs
Switching Speed

Agilent E5052A Signal Source Analyzer & E5053A Microwave Downconverter

Switching Speed

WB: 5.5G-6GHz
Max Input 0dBm
NB: 5.499GHz-5.501GHz

Transient: Hold
Cor Ctrl Pow Attn ExtRef Stop Svc 2009-10-21 04:00
Phase Noise at 10 GHz

-122 dBc/Hz

10k
Phase Noise at 5 GHz

-128 dBc/Hz

10k
Phase Noise

![Graph of Phase Noise](image_url)
Spurious at 10 GHz (100 MHz Span)

- dBm
- 10
- 0
- -10
- -20
- -30
- -40
- -50
- -60
- -70
- -80
- -90
- Centre: 10.0000 GHz
- Span: 100.0000 MHz
- Res BW: 300 Hz
- Vid BW: 300 Hz
- Sweep: 1.15 ks
- 2/3/2011 5:50:02 PM
- FSP-38
Spurious at 10 GHz (10 MHz Span)

10 GHz Span 10 MHz
Trace A
Centre: 10.0000 GHz
Span: 10.0000 MHz
Res BW: 1 kHz
Vid BW: 30 Hz
Sweep: 270.00 s
2/3/2011 2:38:48 PM
FSP-38
Spurious at 10 GHz (1 MHz Span)

10 GHz Span 1 MHz

Trace A

Centre: 10.0000 GHz
Span: 1.0000 MHz
Res BW: 300 Hz
Vid BW: 10 Hz
Sweep: 270.00 s

Spurious at 10 GHz (100 kHz Span)
Spurious at 10 GHz (10 kHz Span)

![Graph showing spurious signals at 10 GHz with a 10 kHz span. The peak is at 10 GHz with a centre frequency of 10.0000 GHz, a span of 10.0000 kHz, a resolution bandwidth of 100 Hz, a video bandwidth of 3 Hz, and a sweep time of 27.00 s. The measurement was taken on 2/3/2011 at 3:06:04 PM using FSP-38.]

-20 dBm
Microphonics

YIG-based

QuickSyn™

Centre: 9.000000 GHz
Span: 10.000000 kHz
Output Power Control
Pulse Modulation

- **On/Off Ratio**: >80 dB
- **Rise/Fall Time**: 10 nSec
- **Min Pulse Width**: 100 nSec
AM and FM Capabilities

AM: DC-100 kHz, 40 dB

FM: DC-100 kHz
Other Capabilities

- Frequency Sweep
- Power Sweep
- List Mode
- Blanking
- Temperature Monitoring
- Lock Recovery
Calibration and Control

- SPI
- USB

- Power Accuracy Calibration (using a power meter)
- Frequency Accuracy Calibration (using a frequency counter)
Industry Recognition

- 1st Prize at ARMMS-2009
- Top Product at Microwaves&RF
- Most Valuable Product at Microwave Journal
- Evaluated by NIST
Questions?

Microwave Frequency Synthesizer

QuickSyn™
A Clean, Fast, and Affordable Frequency Synthesizer
In a Handy Package

T&M performance in your hands!