Alexander Chenakin – RF Industry Icon

Welcome to this episode of the RF Industry Icons podcast, I'm Pat Hindle and today I am talking with Dr. Alexander Chenakin, Senior Director, R&D at Anritsu Company, and world renown expert on frequency sources and synthesizers. He has authored more than 50 technical articles, holds six US patents and published Artech House book, Frequency Synthesizers: Concept to Product. Welcome to the podcast, Alexander!

Hello, everybody! Thank you for your kind words, Pat! I am proud to participate.

When did you come to the United States? What lead you to come to the US?

In 1997 - if I remember correctly - after the collapse of the Soviet Union. This was a big tragedy and difficult time for many people in the country. There were no jobs, no future. I needed to take care of my family and think how to continue my professional career so came to the United States.

What was your first job in the US industry?

The first company I started working in the United States was Celeritek in Santa Clara, California. They were a leading supplier of mm-wave components such as amplifiers, up and down converters and whole transceivers. A very good company! It had an internal Gallium Arsenide foundry as well as alumina substrates and thin-film circuits fabrication. I learned many things there from semiconductor device fabrication processes to building high-frequency components using both chip-and-wire and PCB techniques. And eventually, started working on complex subsystem designs. This helped me to grow professionally. I started as an engineer working all weekends mastering my skills. I ran – quite successfully – several important projects there and then was promoted to a managerial position. But I always liked exploring new ideas and trying something else on my own. I worked at several companies moving forward – step-by-step – from an engineer to executive roles in a number of companies such as Phase Matrix, MicroLambda Wireless and now Anritsu Company.

When did you decide to specialize in frequency synthesis and what lead you in that direction?

Well... The frequency synthesizer is a key element of virtually any RF/microwave system. The industry feels persistent pressure to deliver higher-performance, higher-functionality, smaller-size and lower-cost designs. Frequency synthesizers utilize various techniques and are almost as diverse as the number of their applications. I would say, they are among the most challenging of high-frequency designs that always excites engineers to generate new ideas and try new approaches.

You lead many research projects at Phase Matrix as Vice President there and seems like the most significant development there was the QuickSyn technology – can you tell us about that development and the biggest challenges there?

By that time, Phase Matrix had developed various RF/microwave components and instruments primarily for test-and-measurement applications. Their product lines ranged from frequency counters to sophisticated up and downconverters and frequency synthesizers. After being involved in the industry for several years, I started recognizing a need for frequency synthesizers capable of fast switching speeds. I simply observed a rapid increase in the data-flow rates of the most current microwave systems and saw that synthesizers would need to accommodate this increase. Traditionally, however, there had been compromises with regard to frequency coverage, resolution and spectral purity in order to increase switching speed. That was a big challenge. And one of the most successful developments was – indeed – the QuickSyn synthesizer that helped the company to penetrate many new markets. That product represented a new generation of microwave frequency synthesizers based on a novel technology that provided a unique combination of fast switching speed, very low phase noise and low-cost characteristics.

There are several approaches to generate clean output signals but there is typically a tradeoff between switching speed and phase noise. What method was Phase Matrix using and how did that differ from traditional YIG-based designs?

Historically, high-performance PLL synthesizers have relied on YIG-tuned oscillators featuring broadband operation and excellent phase noise. However, the high-power consumption, large size, and especially low tuning speed, inherent to YIG oscillators, have contributed to a shift to solid-state VCO architectures. VCO-based synthesizers are significantly faster; however, their phase noise has traditionally been considered to be poor when compared to YIG-based designs.

So, there was (and perhaps, still is-?) a belief (or maybe better to say, a myth?) that phase noise and switching speed did not co-exist very well. But, why not? Why can't we have both spectral purity and fast switching speed? Simultaneously. Under the same roof. Does this break any fundamental laws of physics? Should a solution be necessarily super-complex and expensive? Note, we don't necessarily need to rely on free running oscillator characteristics. Our job is to design a synthesizer or, in other words, to lock an oscillator (either VCO or YIG) to a low phase noise reference. As an example, just assume that we use a fast-switching VCO in conjunction with a 100 MHz reference oscillator (such as an OCXO) that exhibits, let's say, -180 dBc/Hz phase noise at 10 kHz offset. If we translate this number to 10 GHz, it corresponds to -140 dBc/Hz at this frequency, that is a state-of-the-art phase noise for any signal generator! The only problem is how to realize such a translation in practice. As always, the devil is in details. Long story short - we did achieve switching speed in the microsecond range along with very low phase noise - comparable (or even superior) to the best industry designs by that time. Interestingly, we accomplished this by using low-cost, tiny VCOs instead of relying on bulky and expensive parts, such as YIGs.

What about design complexity and functionality?

Good question! Another challenge was to increase the synthesizer functionality by implementing various functions such as output power control, output power mute, frequency and power sweep, and list mode. Many applications also required various modulation options such as amplitude, frequency, and pulse modulation. From the first glance, implementing these functions would drastically increase overall instrument complexity and cost.

Not true. Or better to say, not necessarily. I noticed that there were always devices inside the synthesizer that enable these functions. They could be reused to increase functionality without a significant cost penalty. This approach resulted in – what I call – "design density," which included consideration of both component count and functionality per square inch.

Eventually this was a success story?

Yes. This was a success story. Our efforts contributed to the success of Phase Matrix, which helped to make it exceptionally attractive to National Instruments. In May 2011, NI acquired Phase Matrix. In the official press release, NI stated that the "acquisition brings key RF talent, technologies, and manufacturing capabilities to NI and will significantly increase the capability of NI products in high-frequency RF and microwave applications."

Now you are with Anritsu Company in Morgan Hill, California. What is your role there?

I am the Senior Director of research and development, where I oversee the development of various test-and-measurement instruments such as signal generators, vector network analyzers, hand-held spectrum analyzers, power meters and various components. I lead a team of extremely talented engineers working on the most sophisticated and challenging designs inherent in test-and-measurement applications.

Your most recent big development effort at Anritsu Company resulted in the Rubidium signal generator – what lead you to use Rubidium timing?

A signal generator is a quite sophisticated instrument that is supposed to deliver a precise and stable frequency. In other words, if we dial 10 GHz, we should expect a signal exactly at 10 GHz, not 10.012345 etcetera. And we also expect that this frequency will not change in time or with a temperature change. A pretty normal expectation, right? But what is the reality? Signal generator's accuracy and stability depends on an available reference. An ovenized crystal oscillator is today's golden standard for the industry. It is a good device, but is it really stable - if we dive deeper into details? Not quite. Any OCXO frequency depends on its crystal resonator mechanical dimensions, which change with temperature and time (simply because crystal material evaporates – little-by-little). Long story short – in our Rubidium signal generators the reference is disciplined by a Rubidium atomic clock that introduces a much higher degree of accuracy and stability compared to a conventional OCXO-based reference. The atomic clock operation is based on fundamental constants of mother-nature rather than mechanical dimensions and, hence, is extremely stable.

Tell us about the performance specs such as phase noise and how they compare to other signal generators? What design trick did you use?

The Rubidium synthesizer core is based on a proprietary 2-20 GHz YIG oscillator that is locked to an internal reference extracted and distributed by direct analog means. In other words, the YIG output signal is downconverted by a direct analog converter that eliminates any frequency divider and, therefore, phase noise degradation within the phase lock loop. Furthermore, a frequency multiplier is inserted into the loop. Interestingly, this works exactly opposite to a frequency divider – meaning that instead of noise degradation it provides noise improvement or – in other words - additional residual PLL noise suppression. Long story short: The architecture provides essentially a noiseless PLL mechanism translating the synthesizer's reference with no added phase noise degradation (over 20logN fundamentals, of course). In addition, a three-source combined reference is utilized to squeeze every drop of phase noise providing the lowest possible phase noise at any given frequency offset.

As a result, this unique architecture delivers unparalleled performance in respect to spectral purity such as phase noise. Note, phase noise is always a key specification for signal generators. The Rubidium signal generator exhibits -140 dBc/Hz at 10 GHz output and 10 kHz offset, which is better, actually, way better compared to traditional designs currently available on the market. Essentially, the Rubidium signal generators redefine industry standards for both spectral purity and stability.

You are also involved in the IEEE and are the chair of TC-10 Signal Generation and Frequency Conversion Technical Committee, what activities is that committee involved in?

The main mission of the IEEE TC-10 Technical Committee is to promote the development of signal generation and frequency conversion techniques applied to various circuits and systems. This committee includes widely recognized, world-level experts to evaluate new developments in the field of RF and microwave oscillators, frequency multipliers, mixers, and frequency synthesizers. We also promote and support various events such as workshops, student design competitions and many others at large industry conferences and shows such as the IMS (International Microwave Symposium).

You wrote the Artech House book, Frequency Synthesizers: Concept to Product – tell us how you developed that title and any challenges in writing the book?

Frequency synthesizers evolved over time, and this book offered an overview of both well-established and recently developed techniques. It is primarily intended for engineers in their first years of practice and serves as a quick guide to mastering professional skills. It aims to bridge the gap between basic theoretical knowledge and the years of work required to build practical experience in this field. The book gathers a collection of block diagrams, clever circuits, design recipes, and other hard-to-find information usually treated as "design secrets." All the techniques are illustrated with practical examples used in industrial products. I tried to write it in a simple yet rigorous style to provide an all-in-one source for both the beginner as well as the experienced designer. Overall, this was a big project by itself, but it also helped me to summarize my knowledge in this field. Although, this was quite an effort, I really enjoyed working on this book.

What are modern trends in frequency synthesizer developments?

As of today, the indirect (or PLL) architectures remain the most popular approach. However, the most exciting future developments are likely to be associated with the DDS technology that has a tremendous potential for growth. Much of the progress will be brought by extension of DDS usable bandwidth and reduction of its spurious content. At some point, the direct synthesis is expected to compete and eventually substitute indirect designs offering amazingly faster, nanosecond-range tuning speed as well as complex output waveforms. Longer-term, major breakthroughs are expected in operating the reference with other physical principles or materials such as sapphire oscillators or optoelectronic methods. What performance can be achieved? Well… Only the future will tell.

In a more general sense, what new developments are you most excited about in the industry and why?

We clearly observe the increasing need for more capacity and higher data rates in wireless networks. Discussions and even practical research work of beyond 5G and 6G topics has already started in the academic and research communities. Much higher modulation bandwidths (we are taking about tens of gigahertz) are expected. Obviously, this pushes our industry to higher frequencies - towards sub-millimeter waves and Terahertz technologies. These expectations will dramatically change conceptual approaches of building new devices and subsystems - or even the whole way of thinking about it. I am sure, a lot of amazing developments are expected next decades.

Thank you, Alexander, for talking with me about your career and experiences in the industry. You are truly an RF Industry Icon with your work in signal generation. To our audience, you can find more podcasts at podcasts.microwavejournal.com. Thanks for listening.