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[Systems & Subsystems]

When Switching Speed Is Important

Frequency synthesizers capable of fast frequency switching speeds can provide a variety of benefits in commercial and military system and measurement applications.

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Microwave frequency synthesizers provide the stable signals needed in a wide range of modern electronic systems, including communications systems, civilian and miliary radars, and electronic-warfare (EW) systems. They are available in many configuarations, from the tiny integrated circuits (ICs) embedded into cellular telephones to the rugged, rack-mount enclosures used in naval shipboard radar systems. Microwave frequency synthesizers can be compared in terms of many different performance parameters, although one of the clearest differentiators is switching speed.

The switching speed of a microwave frequency synthesizer is a function of circuit topology and synthesizer technology. Microwave and RF synthesizers generate signals based on two types of architecture: indirect and direct synthesis. Indirect synthesizers, which provide the slower frequency switching speed of the two architectures, rely on a variable-frequency tuned oscillator, such as voltage- controlled oscillator (VCO) or YIG-tuned oscillator, that is stabilized in phase to a more precise, lower-frequency reference oscillator. The tuning speed of an indirect frequency synthesizer method is in the range of tens of microseconds at best and usually in the range of milliseconds.

One of the fastest commercial indrect frequency synthesizers is the IBS Series from Elcom Technologies (Fig. 1). The IBS Series synthesizers, which are available from 0. to 6.0 GHz or 0.1 to 20 GHz, achieve switching speeds of 10 to 100 µs with low phase noise and superb spectral purity. The switching speed is a function of the distance between two frequencies, with full-band switching possible in only 100 µs.

In contrast, a direct frequency synthesizer essentially selects an output by means of high-speed switching among different generated frequencies. The frequencies are produced by multiplying and dividing a low-noise reference source and selecting among signals processed through banks of filters. Unlike a VCO or YIG oscillator which must be tuned to a new frequency by means of a change in voltage or current, respectively, the frequencies in an indirect synthesizer are always "on," and can be selected subject to the switching-speed limitations of solidstate PIN-diode or FET switches, which settle in a matter of nanoseconds.

In recent years, direct-digital synthesis-(DDS) technology has improved to the point where these VHF/UHF sources are often incorporated within indirect or direct frequency synthesizers to provide fine frequency steps with fast-switching speed. Combined with traditional directsynthesis techniques, a DDS can form part of a fast-switching frequency synthesizer solution capable of settling to a new frequency in under a microsecond.

The UFS Series (Fig. 2) of broadband direct frequency synthesizers from Elcom Technologies, for example, combines DDS technology for small frequency steps with a direct analog synthesizer architecture to achieve frequency switching speed of 200 ms with 1-Hz resolution over a standard frequency range of 300 MHz to 18 GHz (Fig. 3). Since the UFS Series synthesizers have been designed as a collection of modules that can be added and subtracted as more or less frequency resolution and range is needed, they can be supplied in a traditional rack-mount enclosure as well as a compact VXI format.

It is important to apply a consistent definition of switching speed when comparing frequency synthesizers from different manufacturers. Switching speed can be applied to both output amplitude and frequency and is the delay time required by the synthesizer to change between two frequencies or two power levels or both. The delay is a combination of the time required for the synthesizer's dedicated processor to react to a command, the switch/ blanking time, the dwell time, and the settling time. The switch/blanking time is the delay from when a parallel BCD word is sent to the synthesizer and the new frequency is stable within 0.1 rad of the final output phase or within a given tolerance (±x Hz, depending on the frequency step size) of a new frequency. Blanking refers to the capability of turning off the synthesizer's RF output power during the transition from one frequency to the next, in order to avoid harmonic or spurious signals appearing at the output port during switching.

Frequency-switching characteristics can be further defined in terms of whether or not outputs are phase coherent or phase continuous (Fig. 3). With phasecoherent switching, a synthesizer can shift from one frequency to the next and then back to the original frequency, resuming with the phase that it would have had at that initial frequency had it been running at that frequency continuously. This capability is only possible in a direct analog synthesizer when all output frequencies are generated simultaneously and the synthesizer switches among these possible output frequencies. Phase-coherent switching capability is critical to certain applications, such as coherent pulse Doppler radar systems that use coherent pulse detection for predetection integration. At lower frequencies, phasecoherent synthesizers are also used in NMR/MRI spectrometry systems for medical and material-analysis applications.

Changes in frequency are phase continuous when they do not cause discontinuities in the phase (or amplitude) of the output signal. The first phase value after a frequency change is an increment of the last phase value before the change. A synthesizer capable of phase-continuous switching exhibits almost no transient behavior or noise when switching from one frequency to the next (Fig. 4). This is important in some radar and EW systems when it is necessary to generate an analog-like synthesized sweep, such as the generation of linear frequency modulation (FM) or minimum-shiftkeying (MSK) modulation. Such output signals exhibit phase transitions that are smooth with very little noise.

Why is frequencyswitching speed important? For one thing, in more and more commercial communications applications, frequency agility is the basis for the radio air interface. For example, short-range Bluetooth systems employ frequencyhopping spread-spectrum techniques to achieve moderate data rates from relatively narrowband channels. Shortrange UWB devices rely on time-sequences pulse streams that occupy a relatively wide bandwidth of approximately 3.1 to 10.6 GHz to receive high-date-rate information at low transmit power levels. In both cases, a fast-switching frequency synthesizer can provide the frequency agility needed to emulate the signal sources found in these short-range systems. Another commonplace spread-spectrum communications device that relies on frequency agility is the codedivisionmultiple-access (CDMA) cellular telephone where the frequencyhopping sequence information is embedded in the transmitted signal for the receiver to uncover and decode.

On the military side, secure battlefield-radio systems typically employ encryption along with frequency agility for security. The Link-16 radio used by the US Navy and Joint Services (and manufactured by Rockwell Collins), for example, employs dynamic frequency hopping. The modulated carrier is only a few megahertz wide, but hops across a total spectrum of 255 MHz. The order of the frequencies is determined dynamically, with the transmitter-sending an encoded instruction to the receiver to guide its frequencyhopping sequence. In testing or emulating these radios, a conventional indirect frequency synthesizer with frequency sweep capability will not provide the proper-waveform signature that represents a transmitted Link-16 signal. For this purpose, a direct frequency synthesizer operating under program control through a BCD interface or in a list frequency mode can better approximate the random movement of the modulated carrier across the radio's wide 255-MHz total bandwidth.

In some applications, fast switching speed simply translates into measurement power and throughput. For example, radar cross-section (RCS) measurements are necessary to establish radar signatures for known targets, such as aircraft, ships, and missiles. These signatures are created through tedious measurements at thousands of frequencies at compact indoor ranges as well as at static and dynamic outdoor ranges. Measurements are performed with systems similar to an actual radar transmitter and receiver, relying on a fast-switching frequency synthesizer for transmission and a fast-response, wideband radar receiver for analysis. Testing usually involves the transmission and reception of thousands of radar signals and returns across the surface of a target under test (such as an aircraft) in certain frequency steps (such as 25 or 50 MHz) across a bandwidth of interest (such as 18 GHz). Because of the total numbers of measurements that must be made, testing that might take days with a microsecond-speed synthesizer can take weeks or longer with a frequency synthesizer capable of only millisecond switching speed.

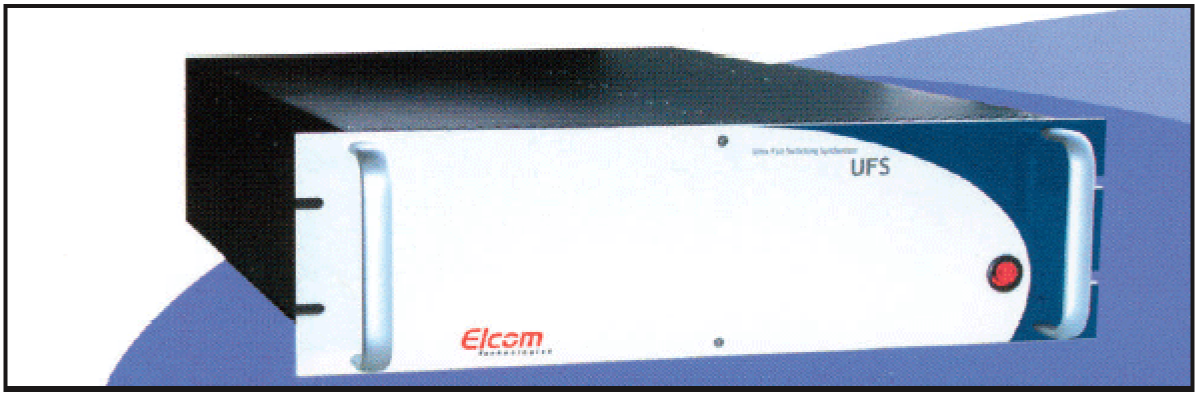
Testing an antenna also requires large amounts of data at multiple frequencies. Measurements on antennas are performed at different types of facilities, including near-field installations and far-field (often outdoor) ranges. The US National Institute of Standards and Technology (NIST), for example, performs near-field antenna measurements on a contractual basis, performing tens and thousands of measurements per frequency through 10 GHz at their facilities in Boulder, CO. As with RCS measurements, the sheer number of these measurements can be tedious and time consuming if relying on a test source with only millisecond switching speed. Importantly, when performing antenna measurements, the test source must provide consistent phase noise during high-speed switching to ensure the accuracy of test data taken across thousands of frequencies and measurement points.

In near-field antenna measurements, the test probe is located close to an antenna under test, with measurements performed over a user-selected bandwidth using a fast synthesizer and a microwave vector network analyzer. To optimize measurement speed, a maximum IF bandwidth is selected for the analyzer. In far-field measurements, which can be performed at a large test facility or typically an outdoor range, high analyzer sensitivity is critical since the source antenna may be located a considerable distance from the antenna under test. For a high-performance vector network analyzer, such as a PNA series instrument from Agilent Technologies, optimized for these measurements, the frequency stepping speed at the maximum IF bandwidth is typically 160 microseconds.[1] This assumes a frequency switching speed of 10 MHz per test point, and implies the switching speed capability of a fast direct synthesizer such as an IBS series source, which maintains low phase noise even at 100-µs switching speeds.

Figure 1

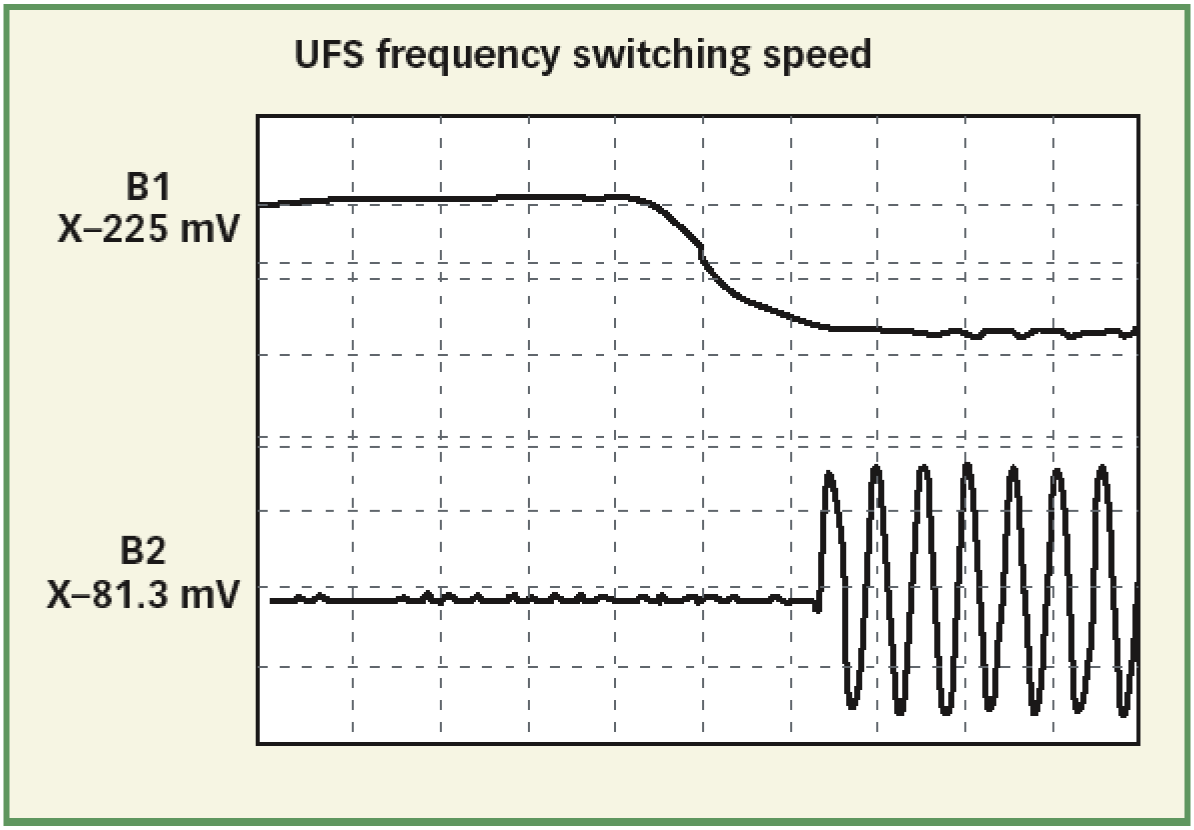
1. IBS Series frequency synthesizers cover frequency bands from 50 MHz to 20 GHz with switching speeds of 100 µs.

Figure 2



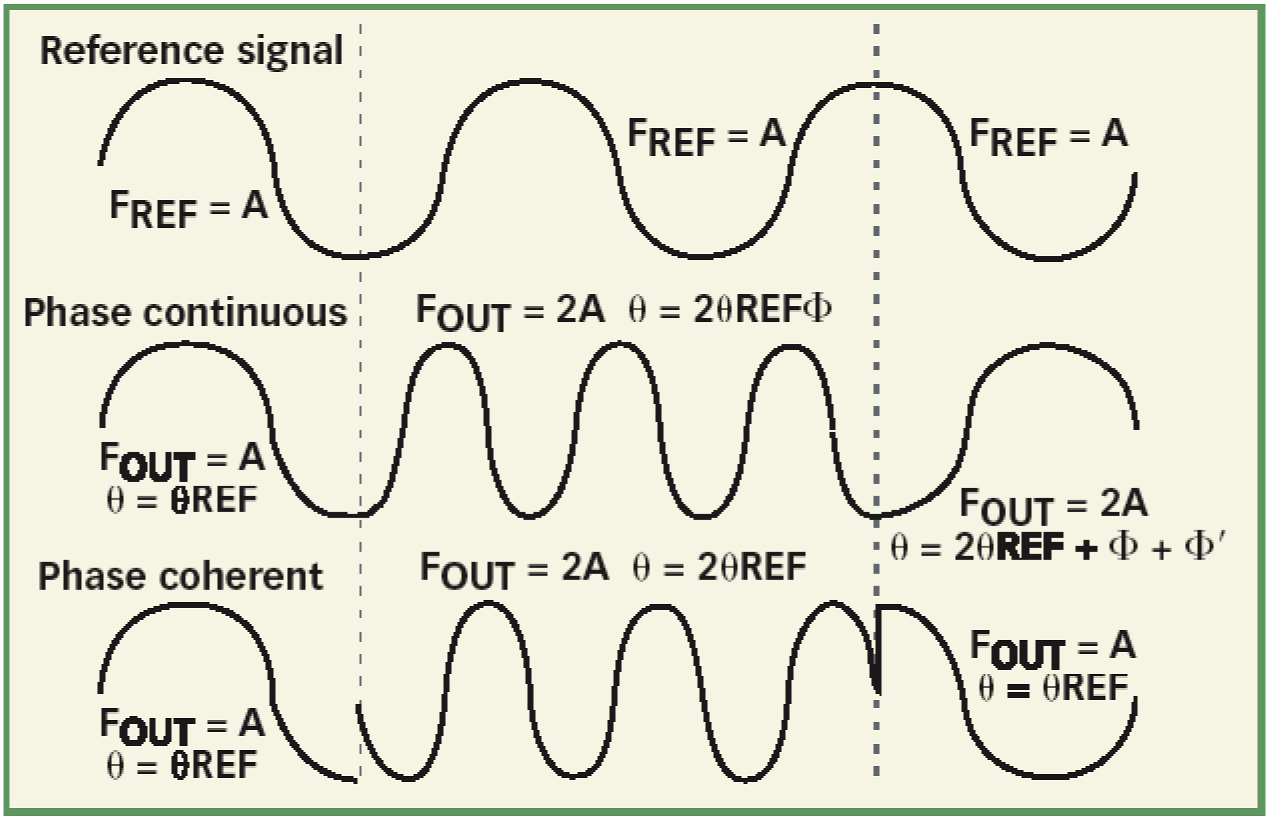
2. UFS Series frequency synthesizers provide resolution as fine as 1 Hz over a standard frequency range of 300 MHz to 18 GHz, combined with 200 nsec switching.

Figure 3


UFS frequency switching speed

3. The combination of direct-analog and DDS technologies in the UFS series results in frequency switching speed of 250 ns or better as shown here for a frequency jump from 9610 to 9643 MHz. The time scale is 50 ns/division.

Figure 4



4. Phase-continuous and phase-coherent high-speed frequency switching are needed for certain applications. The plot shows that phase coherency maintains the phase of a starting point when returning to that frequency after switching, while phase continuity maintains a smooth phase characteristic even with changes in frequency.