THIRD GENERATION AUTOMATIC MICROWAVE MEASUREMENTS

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ABSTRACT

A microwave measurement system is described that is used with our third generation test equipment to achieve automatic microwave measurements of signals in the frequency range of 10 MHz to 18 GHz. This system down-converts input signals in the range of 2 GHz to 18 GHz so that through the utilization of sampling techniques and computer software automatic microwave measurements of frequency, power, spectrum analyses, and modulation are achieved. Signals from 10 MHz to 2 GHz are first up-converted and applied to the microwave circuits for down conversion.

INTRODUCTION

Automatic measurements systems that now exist use dedicated test instruments, which are digitally controlled to make only one measurement. This approach to Automatic Test Equipment (ATE) we will call second generation. We have combined the measurement capability of many of these instruments into one unit which is computer controlled. The unit which replaces the typical measurement instruments; such as: DMM, counter, RMS voltmeter, waveform analyzer, distortion analyzer, was developed at General Dynamics, Electronics Division.[1] The unit is called The Sampling Measuring System (SMS), in which we use sampling to convert voltage waveforms into digital information and then apply computer algorithms to evaluate the required measurement parameters . This unit is the basis of our third generation Synthesized Computer Control Automatic Test Equipment (SCATE).

A unit is now described which replaces several dedicated microwave instruments with one unit which relies on the SMS and computer to make the desired measurement. This approach is an extension of our third generation test equipment into the microwave measurement area. Currently the SMS is restricted to frequencies below 10 MHz. The Microwave Measurement Unit (MMU) is the front-end of a system which down-converts signals from 10 MHz to 18 GHz to the frequency range of the SMS.

MEASUREMENT SYSTEM DESCRIPTION

The basic system shown in Figure 1 is a wideband double-down conversion scheme in which we employ a tuned-harmonic generator as the first local oscillator. Normally in a double-down conversion technique in an ATE application one would require a frequency synthesizer for the first local oscillator to obtain the frequency resolution and maintain reasonable frequency accuracy. A frequency synthesizer which could tune from 10 MHz to 18 GHz would be rather large and expensive. We found that a harmonic generator provides a cost effective solution to this problem. We have in turn transferred the frequency synthesizer requirement to the reduced coverage second local oscillator. Also included in the unit is an input attenuator, a DC to 18 GHz device, which provides 70 dB of attenuation in 10 dB steps. A preselector YIG filter is included for performing spectrum analyses and is switched out of the circuit when it is not needed. Signals between 10 MHz and 2 GHz are first up-converted to frequencies between 2.51 GHz and 4.5 GHz and applied to a microwave mixer using a fixed local oscillator frequency of 2.5 GHz. Signals between 2 and 18 GHz are double-down converted and then routed to either a prescaler and to the counter in the SMS for frequency measurements, or a 160 MHz logarithmic amplifier for receiver and power measurements, or a variable bandwidth bandpass filter for spectrum analyses.

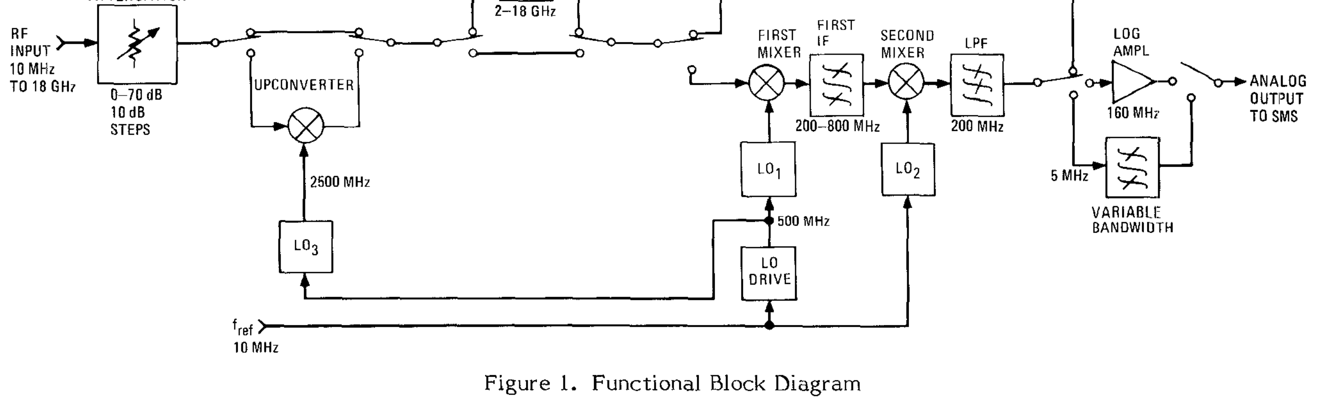

Figure 1. Functional Block Diagram

The prescaler first amplifies the 2 to 200 MHz IF signal and applies the signal to a high speed digital Flip-Flop. The SMS counter measures the frequency and computer algorithms compute the input RF frequency. The logarithmic amplifier is included to provide wide bandwidth receiver measurements such as evaluation of pulse and AM modulation and for making power measurements when precalibrated. The 5 MHz variable bandwidth filter provides the capability of conventional automatic spectrum analyses. The operation of the first and second local oscillators are discussed in subsequent paragraphs. The purpose of the first local oscillator is to produce discrete frequencies which are used to down-convert the input microwave frequencies to a wideband first IF.

FIRST LOCAL OSCILLATOR

The approach that is taken with the first down-conversion is made possible by a biasable 2 to 18 GHz microwave mixer. Using this type of mixer it is possible to use the relative low output power of a YIG tuned harmonic generator as the local oscillator. Figure 2 shows the operation of the first local oscillator more clearly, while Figure 3 shows the details of the hardware used. A SRD harmonic generator produces an output comb of frequencies spaced at the input drive frequency. A YIG tuned filter then selects one of these frequencies for use as the local oscillator frequency. The drive frequency in our case is 500 MHz. This frequency provides a minimum first IF bandwidth of 500 MHz centered at 500 MHz. Overlap was included in the first IF band resulting in a 200 to 800 MHz bandpass characteristic. The first local oscillator drive is a phase locked one watt power oscillator design. This oscillator, along with the second local oscillator are phase locked to the 10 MHz frequency reference of the SMS to provide frequency accuracy.

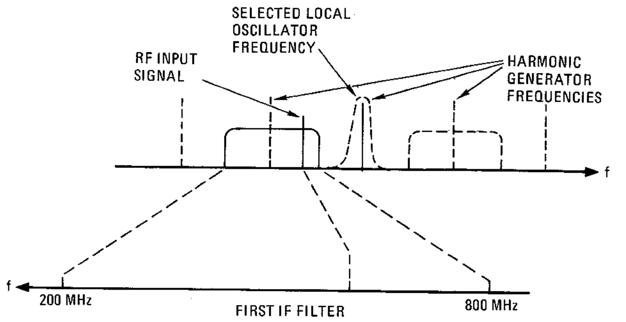

Figure 2. Typical First Down-Conversion Signal Relationships

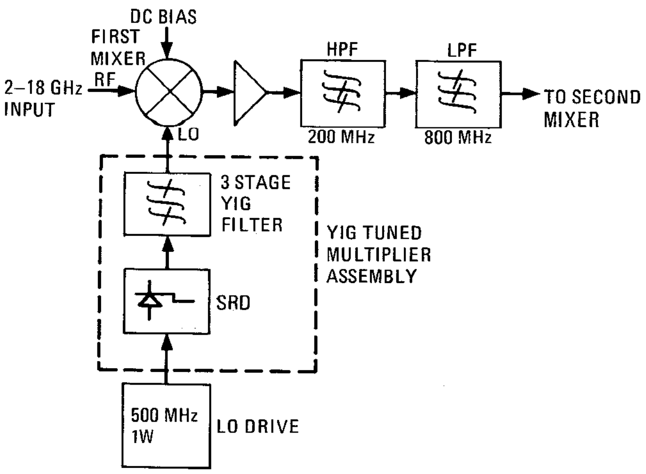

Figure 3. First Local Oscillator

With our approach, phase noise is an important parameter. The second local oscillator is designed with low phase noise; however the phase noise of the first local oscillator drive, P_ϕ, when multiplied by N with the YIG-tuned multiplier becomes, the major phase noise contributor. The phase noise power of the first local oscillator P_{ϕ_0}, is then expressed as

$$P_{\phi_0} = (20 \log N)\, P_\phi \tag{1}$$

The requirement for the first local oscillator drive's phase noise is thus established to be at least P_{ϕ_0}/P_ϕ greater than the phase noise of the second local oscillator. The second local oscillator is required to convert signals in the 200 to 800 MHz first IF band down to the frequency of 2 to 200 MHz for the evaluation channels. System requirements stipulate that this oscillator be a frequency synthesizer capable of high resolution, such as 30 Hz.

SECOND LOCAL OSCILLATOR

The design of our second local oscillator is unique in that we have not used multiple phase locked loops or other available techniques.[2] Our approach was to use a digital phase accumulator to achieve the required frequency resolution over the required output frequency range of 200 to 1000 MHz. The phase accumulator approach to synthesizer design was described recently for a HF application.[3] Figure 4 is the diagram of the 500 to 1000 MHz portion of the synthesizer. Only one phase-locked loop is used with a fixed divider N, where N = 400. The $f_o/2$ output is used to provide the remainder of the frequency range of 200 to 500 MHz. The phase accumulator generates a reference frequency between 1.25 and 2.5 MHz. The phase locked loop then multiplies this signal by a factor of 400. The phase accumulator consist of an M-bit adder and (M+1) -bit storage register, f_1 is the final carry-out pulse train of the accumulator. The average frequency of this signal is used as the reference signal for the phase locked loop. The expression for the output of the phase accumulator is

$$f_1 = F_n f_r 2^{-m} \tag{2}$$

Yielding an output frequency of

$$f_o = \frac{N f_r}{\mathrm{INT}\left\{\dfrac{2^m}{F_n}\right\}} \tag{3}$$

Equation 2, however, is not always an integer; creating phase noise at the synthesizer output which is not filtered by the phase locked loop. Compensation for this noise is provided by the D/A conversion of the 10 least sufficient binary levels from the sum output bits of the M-bit adder. This analog voltage is proportional to the phase error of f_1 and is used to cancel the phase noise in the phase locked loop. Further reduction of phase noise is accomplished by selecting two slightly different reference frequencies, 20 or 21 MHz.

COMPUTER SOFTWARE

The MMU hardware I have described functions only as a frequency converter, filter and amplitude conditioner. Its task is to convert incoming microwave signals down to frequencies and amplitudes which our SMS can handle. The purpose of our computer software is to:

- Set the first and second local oscillators
- Select the measurement path
- Set the SMS to take samples of the signal
- Compute the required parameter value
- Evaluate the measurement

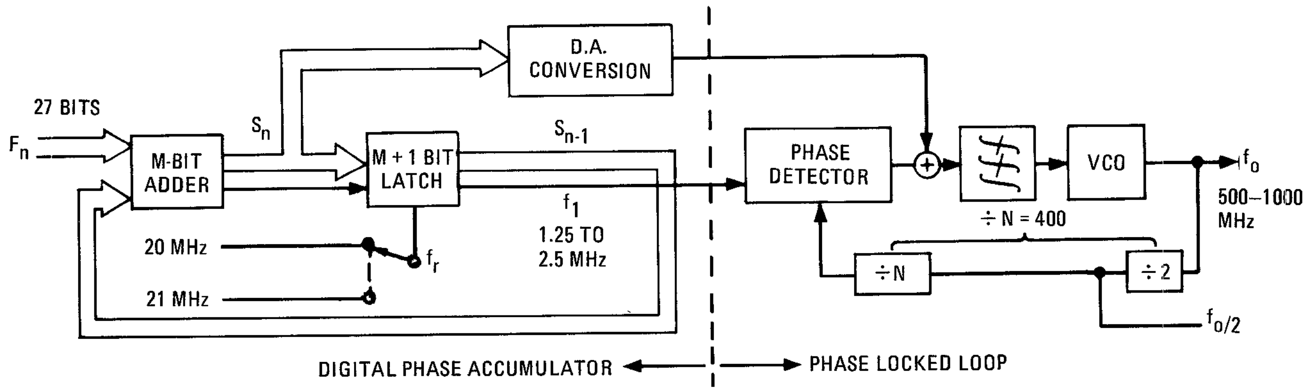

Figure 4. Unique Digital Frequency Synthesizer

The programming language that we use is ATLAS, a high-level automatic test system language. We have created routines to measure RF frequency, power (peak or average), spectral content and modulation parameters. As an example the flow diagram for frequency measurements is shown in Figure 5. This diagram shows the automatic search loop which is used to verify that the proper signal is being counted. We achieve this by starting with the first local oscillator above the desired frequency. If the frequency is unknown we start with the first local oscillator at 18.5 GHz and the second local oscillator at 950 MHz. The second local oscillator is then stepped in 150 MHz steps until a measurable signal is encountered. The input frequency f_Φ is calculated as:

$$f_\Phi = f_{LO_1} - f_{LO_2} + 2 f_m \qquad (4)$$

where f_Φ is the frequency measured by the SMS.

CONCLUSIONS

Using the Microwave Measurement Unit with the General Dynamics Electronics SCATE it is now possible to make RF and microwave measurements in the frequency range of 10 MHz to 18 GHz. The approach taken ensures a timely cost effective solution to the problem of using many instruments to make automatic microwave measurements.

ACKNOWLEDGMENTS

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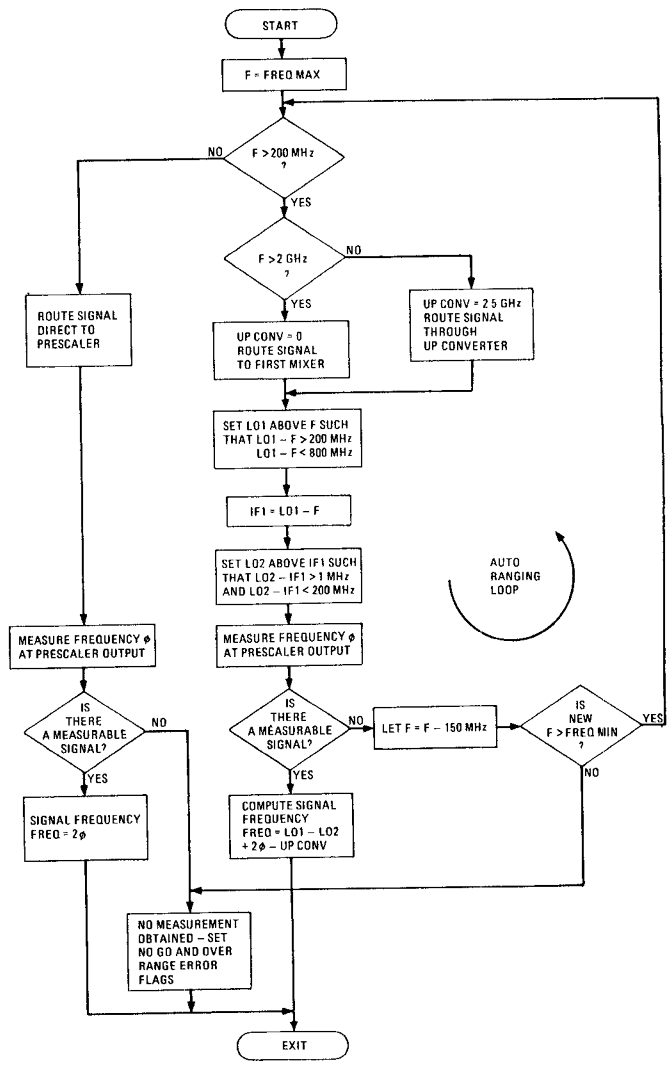

Figure 5. Flow Diagram for RF Frequency Measurement

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