A FREQUENCY CONVERSION SCHEME FOR AN ADVANCED PORTABLE MICROWAVE SPECTRUM ANALYZER

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ABSTRACT

A block diagram is described with an unusually high frequency IF system resulting in a high performance spectrum analyzer. The phase noise and short term frequency stability are not seriously degraded and the sensitivity is enhanced at high center frequencies. This technique also has applications in modern receivers.

INTRODUCTION

Technology improvements over the last few years have made possible several advances in portable microwave spectrum analyzers. This paper shows how these changes in materials and device technology have had a direct impact on the block diagram and frequency conversion selection. Typical performance numbers for some of the components and their effect on the system will be illustrated.

ANALYZER CHARACTERISTICS

A typical rank ordered list of desired spectrum analyzer characteristics follows:

- Frequency range
- Dynamic range
- Signal resolution
- Phase noise measurement ability
- Sensitivity
- Precision of measurements

Each of these topics will be discussed in the following sections.

FREQUENCY RANGE

The most direct way to increase the frequency range of any frequency scheme is to raise all of the frequencies involved. The resulting block diagram is shown in figure 1.

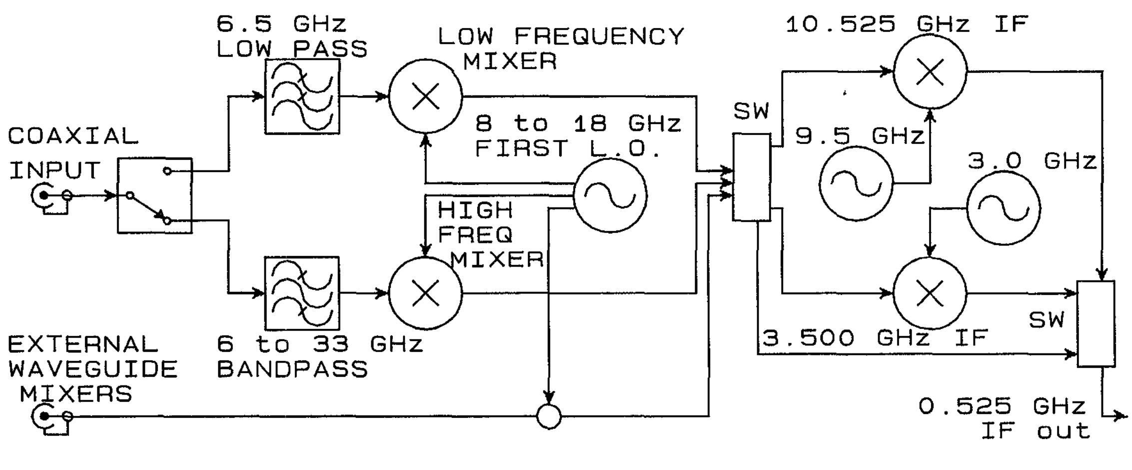

Figure 1. Simplified Block Diagram.

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The development of GaAs transistor technology has made possible the realization of low cost, very low noise figure multi-GHz IF amplifiers having excellent third order intermodulation products. This has made it reasonable to increase the first IF frequency up to 10 GHz or higher if desired. The exact IF frequencies were dictated by the desire to have the L.O. frequencies an integral multiple of 100 MHz. This simplified the phase lock system for the second local oscillators.

This same transistor technology has also made it practical to produce wide tuning range high frequency YIG-tuned oscillators. The one used in this instrument tunes from 8 to 18 GHz and has a phase noise performance of −125 dBc/Hz at 500 KHz offset from the carrier.

DYNAMIC RANGE

On-screen dynamic range (the ability to see large and small signals simultaneously) requires low noise IF amplifiers that can handle large signals with minimum distortion products. These GaAs circuits can accomplish 3 dB noise figure and +25 dBm intercept. GaAs amplifiers for the 18 GHz L.O. provide the +17 dBm power required for the high-level mixers needed in the front end.

SIGNAL RESOLUTION

For a spectrum analyzer to actually resolve closely spaced signals it must not only have an IF filter that is at least as narrow as the spacing of the signals to be resolved, it must also have low enough residual FM to cleanly display this filter. The synthesizer block diagram is optimized to allow sweeping the 18 GHz L.O. over narrow frequency spans with less than 1 Hz incidental FM. This is accomplished by having the synthesizer arranged to sweep the L.O. the same number of Hertz as the swept oscillator in spans of more than 20 KHz. The ratio is one-tenth for spans 20 KHz and less. The incidental FM is only degraded by the narrow swept oscillator not by the synthesizer.

PHASE NOISE

The impact of raising the L.O. and IF frequencies has some potential disadvantages. The most serious effect is on the phase noise of the first L.O. The phase noise of a carrier increases as 20 LOG N where N is the ratio of multiplication. [1] This is the effect observed when multiplying the 100 MHz reference to phase lock the first L.O. This set of problems has been solved by using a conventional sampling type phase detector with a strobe rate of about 130 MHz. (Figure 2.)

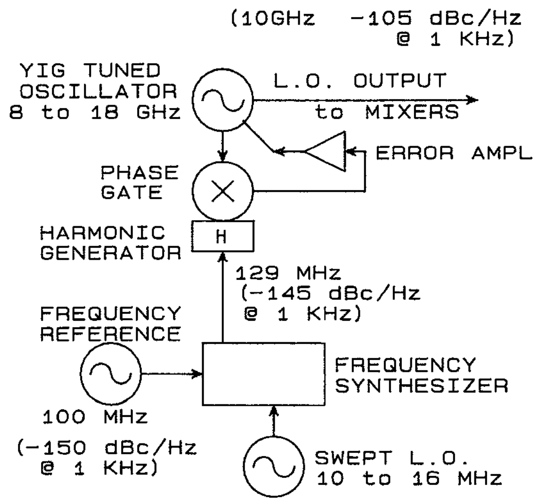

Figure 2. Simplified Lock Circuits.

The synthesizer that generates the strobe frequency just slightly degrades the phase noise of the 100 MHz reference and can be swept a small amount. Since the sampling rate is about 130 MHz and the first L.O. is as high as 18 GHz, the phase noise of the 18 GHz L.O. is degraded by as much as 42 dB more than the phase noise of the 130 MHz strobe. This is much less than the degradation which would have resulted if the sampling rate were, for example, 5 MHz which would cause 70 dB more phase noise. (Figure 3.)

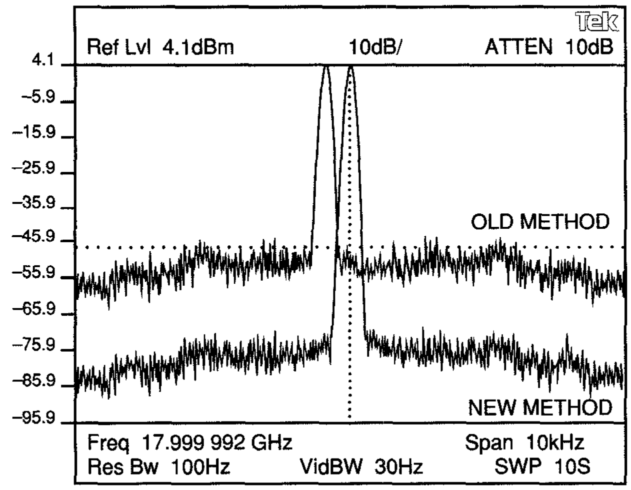

Figure 3. Phase Noise.

A similar type of lock system is used for the second L.O. Both the first and second L.O.s use the same reference and are phase locked with similar loop bandwidths. This cancels the major expected contribution to phase noise from the reference. Thus the displayed phase noise is approximately that of the reference multiplied to the desired center frequency not the L.O. frequency. The major contributions to the phase noise at low center frequencies are the residual noise in the lock system components and the noise from the swept low frequency L.O.

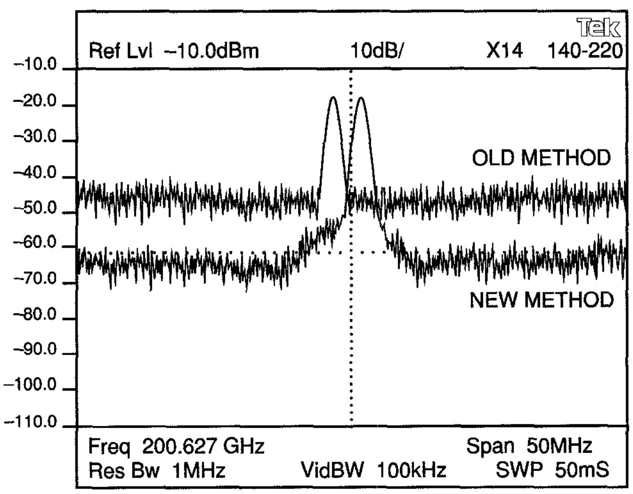

Figure 4. Sensitivity.

SENSITIVITY

The high frequency of the first L.O. (8 to 18 GHz) allows lower harmonic mixing ratios to be used with the resulting improvements in sensitivity. This is illustrated in figure 4.

PRECISION

This block diagram allows using a very wide bandwidth preselector that needs no re-peaking. (A common problem in the past.) Wide bandwidth is realized by using a high 4πMs material. [2] It is an aluminum doped lithium ferrite with a saturation magnetization of about 2600 Gauss.

The minimum usable frequency of this material is rather high. The actual low end of the preselected bands was determined by a practical realization of the low pass input filter. The high 4πMs of the resonator material has allowed the preselector to be built using small geometry, since the coupling is proportional to 4πMs. [3]

The reduced size has prevented undesired resonances. Even with the size reduction a minimum bandwidth of 100 MHz was obtained. The high IF permits a wider bandwidth preselector without image problems. This wide bandwidth makes it easier to track the filter with the center frequency of the instrument. This ensures good amplitude measurement accuracy over the 6 to 33 GHz range of the preselector. [4]

A graphical technique in combination with a computer based spread sheet was used to examine the system for spurious responses and to optimize the frequency coverage of the external mixer bands above 33 GHz.

The goal was to cover each band with the lowest possible harmonic of the first L.O. and to allow coverage with two IF frequencies. Both the lower frequency first IF and also an IF of .525 GHz, must be workable and meet the additional constraint of not changing the harmonic of the first L.O. over the traditional waveguide frequency bands.

In order to identify the correct mixer response, either of the two IF frequencies can be used with corresponding shifts in the first L.O. frequency to keep the correct center frequency. This is done on operator demand and provides an identification system in the external mixer frequency ranges to help identify undesired spurious responses.

Measurement precision is also enhanced by storing the amplitude characteristics of the whole system and correcting the results at the time signals are displayed on the analyzer.

CONCLUSION

The block diagram and frequency scheme for a high performance spectrum analyzer has been shown. Although these technology advances have been applied to all the noted characteristics of spectrum analyzers, the greatest gain has been made with the high L.O. frequency. This has been accomplished without degrading overall phase noise or short term frequency stability.

ACKNOWLEDGEMENTS

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