A Simple Technique for Measuring Signal Source Noise

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Abstract-Any practical oscillator has fluctuations in its amplitude and frequency. These fluctuations represent random amplitude modulation and phase jitter in the time domain. In the frequency domain there is a broadening of the signal frequency spectrum around a nominal frequency. The basic noise is a quantification of the quality of each oscillator and generator, and a measure of the quality of the equipment and of the system in which they are used. These noises determine the external interference immunity of all equipment and the interferences generated in the most frequent applications, in radio communication systems by themselves will work outwards.

I. Introduction

The typical course of the power spectrum of a free running oscillator is depicted in Fig. 1. The power spectrum goes down rapidly in the near neighbourhood of the nominal frequency, in the area where $\Delta\omega/\omega \approx 10^{-2}$ to 10^{-3}. Further, this decrease stops at greater frequency offsets and the power spectrum level is constant and independent from the frequency. Spectrum components with a high level near the nominal frequency are mainly determined by the phase signal noise, neglecting the flicker noise transposition in the nearest neighbourhood of the carrier [1]. The outlying components, which have a lower value, are caused by amplitude fluctuations. Therefore the phase noise is observed first of all. Its level is characterized by the ratio of the single sideband noise power in the 1Hz bandwidth on the offset frequency $\Delta\omega$ - P_N (ω_0+ $\Delta\omega$, 1Hz), and the total power under the power spectrum P_C [2].

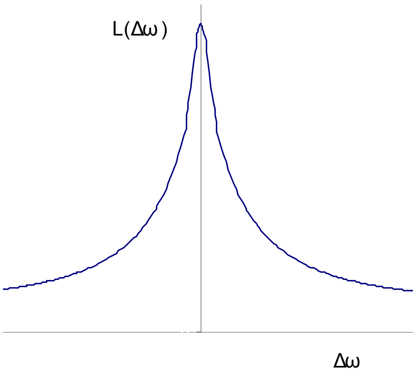

Figure 1. The power spectrum of free running oscillator

$$L(\Delta\omega) = 10 \log(P_N/P_C) \quad (1)$$

II. Phase noise measuring methods

Common methods for measuring phase noise are:

- PLL method with reference source
- Dual reference PLL method with cross-correlation
- Delay pour method
- Direct spectrum analysis

The PLL method with a reference source gives good results, provided that there is a reference source that is better than the measured source from the standpoint of signal noise. The dual reference PLL method with cross - correlation solves this deficiency. This method compensates the influence of the various types of noise of the reference source. However, minimal availability is a weakness of these systems; the measuring systems are very expensive and require very special apparatus.
The delay line method enables measurement of very low noise at a distant out-carrier offset and with a relatively simple device. The disadvantage of this method is that it cannot be used for close in-carrier measurements. There the necessary delay would be very high.
Direct spectrum analysis enables easy operation and quick checks on the signals. Spectral analysers are nowadays the standard apparatus. The impossibility to measure low noise that is levels is a dis-advantage of the method in cases when the tested signal source has noise that is not markedly higher

than a local oscillator of the spectrum analyser. The minimal measurable values are then usually beyond –100 to -110 dBc/Hz for an offset 1 to 10 kHz.
This situation can be improved by correction the measured signal with the use of a filter. We reduce the dynamic range of the signal on the filter output by suppressing the carrier.

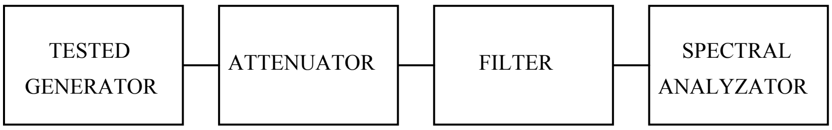

Figure 2. The block schema of the measurement system

The basic connection of a measuring arrangement is illustrated in Fig. 2. Near the carrier of the monitored signal the filter works as a notch filter with very narrow frequency characteristics and with high attenuation on the frequency of the carrier. The attenuation of the filter is already small outside the frequency of the carrier. This ensures that the filter translates the signal noise near the carrying frequency that we want to observe, without major distortion. The minimum measurable noise values are decreased by approximately carrier suppression level.

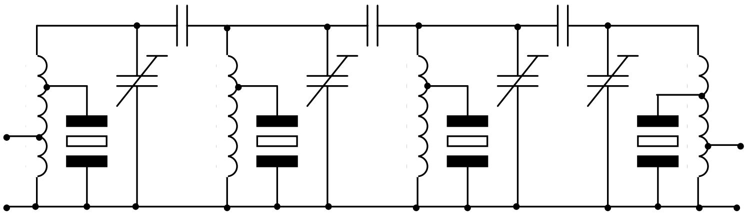

Figure 3. Schema of the filter

The filters were realized as band-pass filters with a bandwidth approximately 10 % of the mean frequency [3]. The block diagram of the filter is illustrated in Fig. 3. The construction emerges from the structure of capacitive coupled identical parallel-resonant circuits, which are optimised for an abnormal approximation near Cebysev. Quartz crystal resonators are connected parallel to the capacitors of the resonant circuits in order to construct of a very narrow band notch filter characteristic.
The choice of the coupling between the crystal resonator and the resonant circuit has a decisive effect on the behaviour of the filter. A near coupling ensures high asymmetry of the filter amplitude characteristic in the transmission band due to high changes if the equivalent capacity of a crystal resonator around a serial and especially a parallel resonant frequency. With a loose coupling only slight attenuation is achieved in the attenuation band.
The transmission of the filter decreases on the serial resonant frequency of quartz resonators. With optimal matching the decrease is approximately 20 to 30 dB for one resonant circuit. An example of the amplitude characteristic of a four-crystal filter is presented in Fig. 4 and Fig. 5.

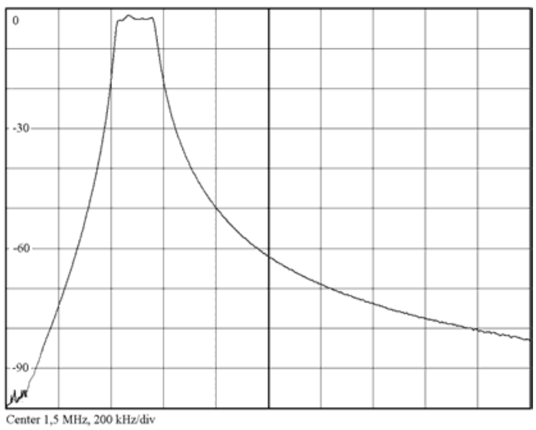

Fig. 4. Amplitude characteristic of filter

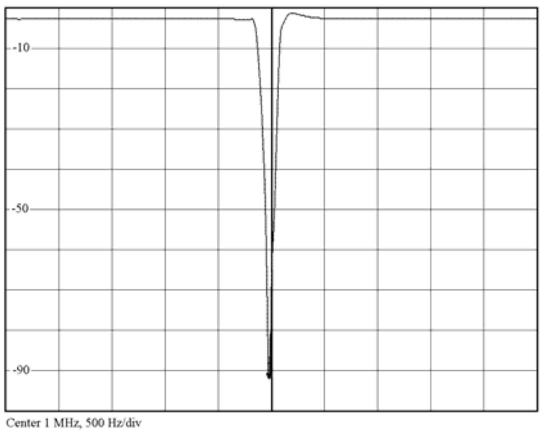

Fig. 5. Amplitude characteristic of filter

Fig. 4 presents the amplitude characteristic of a 1 MHz filter in a broad frequency range from 0,5 to 2,5 MHz. There is a noticeable bandpass filter characteristic with a bandwidth of about 150 kHz. The

rejection area is not noticeable, because the displayed frequency characteristic is only composed of some hundreds of samples in discreet frequencies, and the rejection area is not captured. The rejection frequency area of the filter is displayed in Fig. 5. The rejection frequency area width is about 200 Hz, the attenuation at frequency 0,99998 MHZ exceeds 90 dB.
Similar filters with similar results were also realized at higher frequencies in the range up to 135 MHz.

III. Measurement results on a chosen signal source

Primary measurements were made on to special low level noise oscillators according to the above-mentioned principle. The oscillators were constructed as controlling oscillators of radio communication apparatus. The filter input power was chosen as 10 dBm, in order to prevent noticeable non-linear distortion and to ensure that the resonators were not exposed to power overloading. An example of a measured course of the phase noise spectrum of a variable frequency crystal oscillator [4] with the frequency multipliers at frequency 135,12 MHZ is presented in Fig 6.
The noise to carrier ratio is more than 160 dBc/Hz in the near vicinity of the carrier, and it increases slightly with greater frequency distance. It is evident that these levels of the indicated signals are very small. The measured noise to thermic noise (-174 dBm/Hz) ratio achieves only about 20 dB. It is necessary to protect the measuring system fully against interference signals during measurement and to prevent them entering a measuring circuit from outside.
The power supply of the tested generator and the power supply and power network connection can also have a great influence. The power network is always a reliable interference source. Its influence is evident in Fig. 6 and Fig. 7. Fig. 6 presents the noise spectrum in the case of an accumulator powered oscillator. Fig. 7 presents the noise spectrum of an identical oscillator using a laboratory power supply. The noise level is at least 10 dB lower with the use of an accumulator.

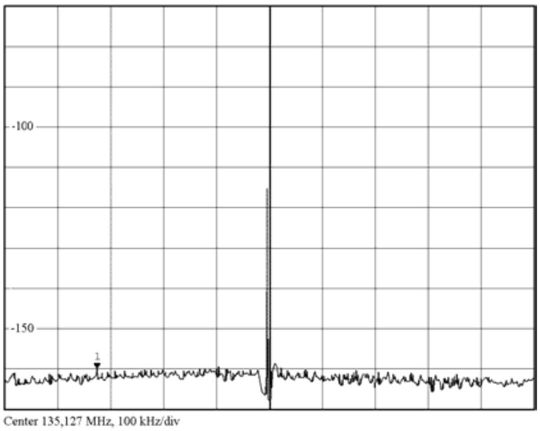

Fig. 6. The phase noise (dBc/Hz) of crystal oscillator with accumulator power supply

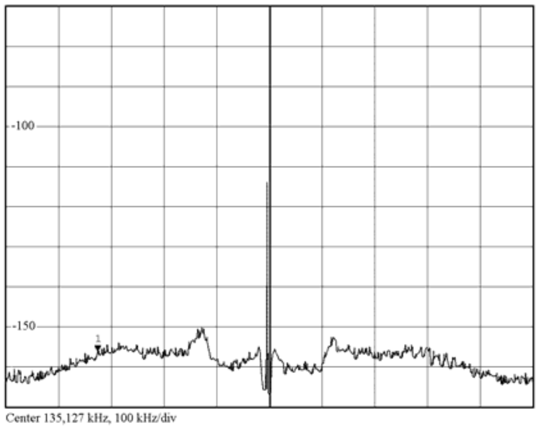

Fig. 7. The phase noise (dBc/Hz) of crystal oscillator with network power supply

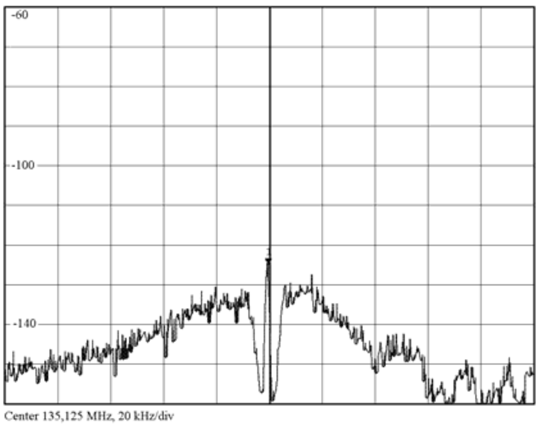

Fig 8 . The phase noise (dBc/Hz) of PLL oscillator

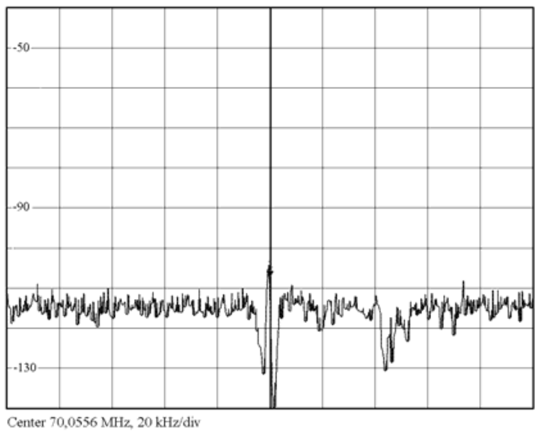

Fig 9 . The phase noise (dBc/Hz) of service signal generator G4-116 (CCCP)

Generators with frequency synthesis usually reach level noise to carrier ratios. The measured course of a phase noise spectrum of the generator for a radio communication arrangement with PLL is introduced in Fig. 8. Fig. 9 displays the measured course of the phase noise spectrum of the G4-116 (CCCP) signal generator.

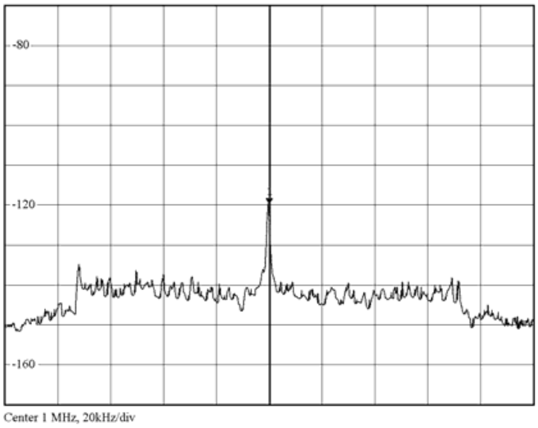

Fig 10. The phase noise (dBc/Hz) of generator Agilent A 33120

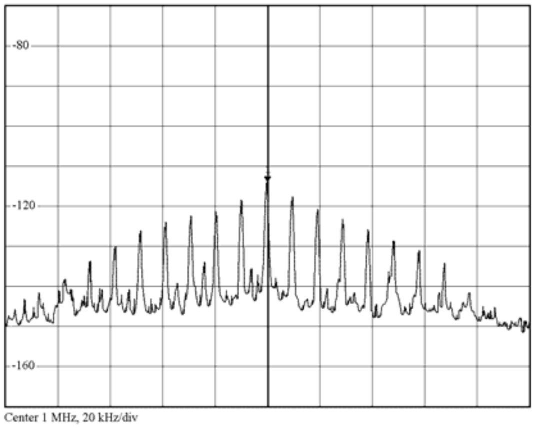

Fig 11. The phase noise (dBc/Hz) of generator Agilent A 33220

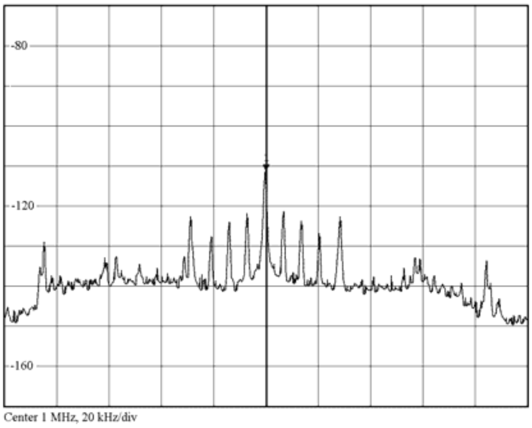

Fig 12. The phase noise (dBc/Hz) of generator Agilent A 33250

Signal sources of a standard functional generator also give similar results. Measured courses of phase noise spectrum of Agilent A33120, A33220 and A33250 generators are presented in Fig. 10-12.

The oldest generator A33120, which gives a sideband phase noise to carrier ratio of nearly 140 dBc/Hz, provides the best results. Newer generators perform less well. Their output signal includes further disturbance on discreet frequentcies. This is probably caused by infiltration of disturbance signals from the switching power sources of the apparatus.

IV. Conclusions

The use of a spectrum analyser for measuring of signal sources noise is described in this paper.

When a simple filter is used, a signal with a noise floor approximately to–160dBc/Hz can be evaluated with a standard spectrum analyser. However, it cannot be used for close in-carrier measurement in the rejection area of a note filter. However, it can be used in practice to evaluating most of the widely-applied radio communication arrangements.

Acknowledgement

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References

[1] J.Everard, Fundamentals of RF Circuit Design with Low Noise Oscillators, John Willey and Sons, LTD, Chichester, 2001, ISBN 0 471 49793 2

[2] A.Hajimiri, The Design of Low Noise Oscillators, Kluwer Academic Pub, 1999, ISBN 0792384555

[3] L. Asbrink, Receiver Dynamic Range, Dubus, 4/2004,pp. 9-39

[4] U.L.Rohde, J.C.Whitaker, T.T.N.Bucher, Communications Receiver: Principles and Design, 2nd Edition, McGraw Hill, 1997, ISBN 0-07-053608-2