ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

A Study on BASICS OF A SPECTRUM ANALYZER

Sibu Thomas[1], Nishi Shahnaj Haider[2]

Assistant Professor, Dept. of CS, S.T.C. College, Bhilai, Chhattisgarh, India[1]

Assistant Professor and Head, Dept. of AE&I, B.I.T.R, Engineering College, Raipur, Chhattisgarh, India[2]

ABSTRACT: This paper describes about a spectrum analyzer that how a Spectrum analyzer usually display raw, unprocessed signal information such as voltage, power, period, wave shape, sidebands, and frequency. They can provide you with a clear and precise window into the frequency spectrum. Also it discusses its function and requirement of a spectrum analyzer in signal analysis. Also it discusses the types of spectrum analyzer and their various applications in factories and in laboratories.

Keywords: Local Area Network, Cathode Ray Tube, Direct Current, Amplitude modulation, Television, Liquid Crystal Display, Fast Fourier Transform.

I. INTRODUCTION

A spectrum analyzer is an instrument which measures the magnitude of an input signal versus frequency within the full frequency range of the instrument. The primary use is to measure the power of the spectrum of known and unknown signals. The input signal a spectrum analyzer measures is electrical, however, spectral compositions of other signals, such as acoustic pressure waves and optical light waves, can be considered through the use of an appropriate transducer.
Like an oscilloscope, a spectrum analyzer produces a visible display on a screen. Unlike an oscilloscope, however, the spectrum analyzer has only one function-to produce a display of the frequency content of an input signal. (But it is possible to display the time waveform on the spectrum analyzer screen with the proper settings.) And also like an oscilloscope, the spectrum analyzer will always produce a picture on the screen; but if you do not know how to properly use the spectrum analyzer, that picture may be completely meaningless.

By analyzing the spectra of electrical signals the following parameters can be easily estimated:

i) dominant frequency
ii) power, distortion
iii) harmonics
iv) bandwidth and
v) Other spectral components of a signal can be observed that are not easily detectable in time domain waveforms.

These parameters are useful in the characterization of electronic devices, such as wireless transmitters.

Spectrum analyzers are instruments that are used to receive and select frequency levels based on the superheterodyne principle. It is very sensitive, converting higher frequencies of up to 10s GHz into something that is measurable. Received frequencies are first put into a series of pre-selected values.

These are then converted into a frequency that is selected to a DC level that is measurable. Often the values are converted into the logarithmic scales. These values are then displayed in the CRT, with the signal strength in the y-axis and the frequency in the x-axis.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

Signals that are weaker than the noise in the background cannot be measured by the spectrum analyzer, power levels that are often seen in microwave receivers. Here, the received signals are measured in decibels rather than voltage because of the low signal strengths that are received and the frequency range of the measurements.

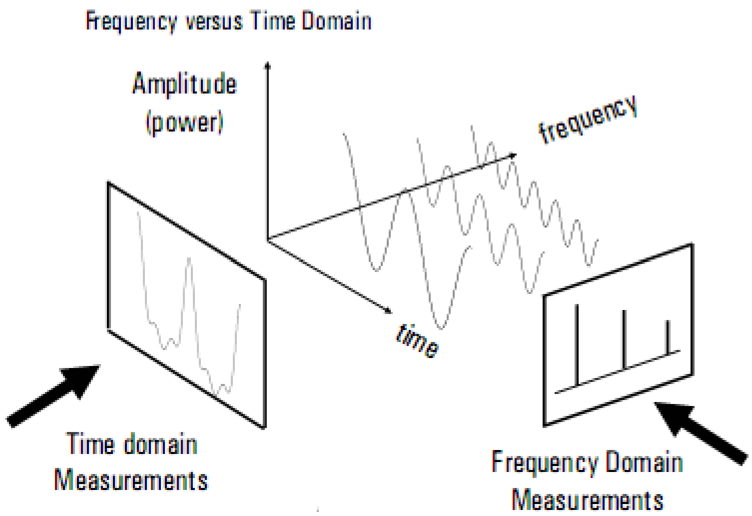

Fig. 1 amplitude versus frequency measurement

Depending upon the application, a signal could have several different characteristics. For example, in communications, in order to send information such as your voice or data, it must be modulated onto a higher frequency carrier. A modulated signal will have specific characteristics depending on the type of modulation used. When testing non-linear devices such as amplifiers or mixers, it is important to understand how these create distortion products and what these distortion products look like. Understanding the characteristics of noise and how a noise signal looks compared to other types of signals can also help you in analyzing your device/system.

Fig. 2 spectrum analyzer

Spectrum analyzers also allow you to have remote control over LAN and the Internet as well as update firmware, add new features and fix problems in the program. Some spectrum analyzers also have provisions for diagnostics and self-calibration. Spectrum analyzers may seem really technical and scientific to the ears. This is because spectrum analyzers are often used in factories and in laboratories for analyzing the signal frequency. Other measurements that the device can handle are measurements of return and loss as well as spurious signals; and alignment of satellite antenna.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

II. TYPES OF SPECTRUM ANALYZER

Spectrum analyzer can be of basically two types:

1) Scanning type or superheterodyne type

2) Non scanning type or Real time spectrum analyzer

3) FFT spectrum analyzer

1) **Scanning type spectrum analyzer or superheterodyne spectrum analyzer:**

The super-heterodyne spectrum analyzer, sometimes called a scanning spectrum analyzer or sweeping spectrum analyzer, operates on the principle of the relative movement in frequency between the signal and a filter. The important parameter is the relative frequency movement. It does not matter whether the signal is stationary and the filter changes or whether the filter is stationary and signal is made to change the frequency.

The technique most widely used is superheterodyne. Heterodyne means to mix - that is, to translate frequency - and super refers to super-audio frequencies, or frequencies above the audio range. Very basically, these analyzers "sweep" across the frequency range of interest, displaying all the frequency components present. We shall see how this is actually accomplished in the next section. The swept-tuned analyzer works just like the AM radio in your home except that on your radio, the dial controls the tuning and instead of a display, your radio has a speaker.

Super-heterodyne spectrum analyzer is the most common type of interest usable up to GHz order range of frequencies. Almost all modern spectrum analyzers employ the super-heterodyne principle. The fact that it provides better resolution and frequency coverage outweighs the fact that it is more complex than other types of analyzers. The super-heterodyne system is based on the use of a mixer and a local oscillator. The horizontal axis of the LCD can now be transformed from the time domain to the frequency domain by varying the local oscillator frequency in synchronization with the horizontal position voltage. Compared with the tuned filter analyzer performing the time-to-frequency domain transformation by varying the frequency of the filter with respect to the signal, the super-heterodyne analyzer performs this transformation by effectively varying the signal at the mixer output with respect to the filter frequency. A basic super-heterodyne spectrum analyzer uses two mixers, a fixed frequency filter and a variable resolution filter, in addition to other basic components

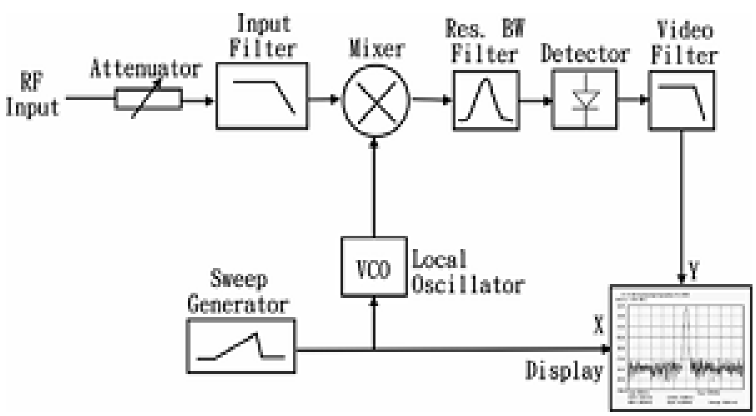

Fig. 3 Superheterodyne spectrum analyzer

needed to display results on a LCD. Note that the variable resolution filter can be designed with a narrow bandwidth because the signal frequency has been substantially lowered by using two heterodyne stages. The filter is designed to have a bandwidth that can be varied manually. This is an important feature because it is normally desirable to use narrow resolution to observe signals that are close together and wide resolution to observe signals that are far apart.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

So we shall choose instead an IF above the highest frequency to which we wish to tune. In Hewlett-Packard spectrum analyzers that tune to 2.9 GHz, the IF chosen is about 3.6 (or 3.9) GHz. Now if we wish to tune from 0 Hz (actually from some low frequency because we cannot view a to O-Hz signal with this architecture) to 2.9 GHz, over what range must the LO tune? If we start the LO at the IF (LO - IF = 0) and tune it upward from there to 2.9 GHz above the IF, we can cover the tuning range with the LO-minus-IF mixing product. Using this information, we can generate a tuning equation:

$$\mathbf{f_{Bi,} = f, - f_{rr}}$$

where fmi, = signal frequency,
f = local oscillator frequency, and
!i = intermediate frequency (IF).

If we wanted to determine the LO frequency needed to tune the analyzer to a low-, mid-, or high-frequency signal (say, 1 kHz, 1.5GHz, and 2.9 GHz), we would first restate the tuning equation in terms of f_{Lo}:

$$\mathbf{f_{LO} = f_{Bi,} + f_{W}}$$

1.1 Advantages:

1. it provides better resolution,
2. it provides better frequency coverage.

1.2 Limitation:

1. it is more complex than other types of analyzers.

1.3 Applications

The swept receiver technique enables frequency domain measurements to be made over a large dynamic range and a wide frequency range, thereby making significant contributions to frequency-domain signal analysis for numerous applications which are as follows:

i. the manufacture and maintenance of microwave communications links, radar, telecommunications equipment,
ii. cable TV systems, and broadcast equipment;
iii. mobile communication systems;
iv. EMI diagnostic testing;
v. component testing; and
vi. Signal surveillance.

2) Non scanning type or Real time spectrum analyzer:

A real time spectrum analyzer operates in a different way to that of a normal swept or superheterodyne spectrum analyzer. This analyzer is free from any type of tuning. It works on real time signal generated on real time basis.

The analyzer can acquire a particular bandwidth or span either side of a centre frequency. The analyzer captures all the signals within the bandwidth and analyses them in real time.

To achieve their performance a real time spectrum analyzer captures the waveform in memory and then uses a fast Fourier transform technology to analyze the waveform very quickly, i.e. in real-time.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

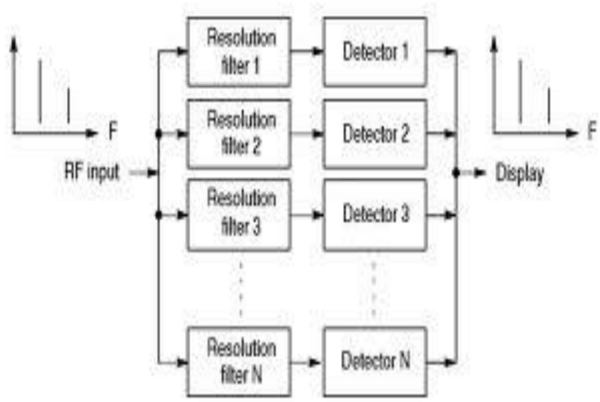

Fig. 4 Multichannel Real-time spectrum analyzer concept

Figure above shows a multichannel real time spectrum analyzer which has a number of Band pass filter, which can accept any range of Signal occurrences which if lies within the range of filter. Maximum range of Filter can be of the range of several kHz. This technology cannot be used for high range of signal detection as it requires large number of filters. RF signal at input is applied to this filter. RF signal if passed by the filter then is sent to detector circuit which finally sends the detected signal to the CRT for display.

By analyzing the waveform in this way, transient effects that may not be visible on other forms of spectrum analyzer can be captured and highlighted. The real-time spectrum analyzer is conceptually equipped with a series of band pass filters. Signals passing through those filters are concurrently observed and recorded continuously.

2.1 Characteristics of real-time spectrum analyzers

- They are based around an FFT - Fast Fourier Transform spectrum analyzer. This will have a real-time - very fast - digital signal processing engine capable to processing the entire bandwidth with no gaps.
- An ADC - analogue to digital converter capable of digitizing the entire bandwidth of the pass band.
- Sufficient capture memory to enable continuous acquisition over the desired measurement period.

2.2 Application

- Signal quality analysis of analog and digital modulation
- Understanding frequency and spectral occupancy behavior over time
- Capture and characterization of undesired, unknown, or interfering signals
- VCO/synthesizer design
- RFID device characterization
- General purpose digital modulation vector signal analysis
- Spectrum monitoring
- Characterization, troubleshooting, and verification of wireless designs (GSM/EDGE, W-CDMA, HSDPA, WLAN 802.11a/b/g etc)

3) **FFT Spectrum Analyzer:** The Fast Fourier Transform spectrum analyzer uses digital signal processing techniques to provide in depth waveform analysis with greater flexibility than other methods. The FFT or Fast Fourier Transform spectrum analyzer uses digital signal processing techniques to analyzer a waveform with Fourier transforms to provide in depth analysis of signal waveform spectra.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

With the FFT analyzer able to provide facilities that cannot be provided by swept frequency analyzers, enabling fast capture and forms of analysis that are not possible with sweep / superheterodyne techniques alone. An FFT spectrum analyzer works in an entirely different way. The input signal is digitized at a high sampling rate, similar to a digitizing oscilloscope. Nyquist's theorem says that as long as the sampling rate is greater than twice the highest frequency component of the signal, then the sampled data will accurately represent the input signal. In this analyzer, sampling occurs at 256 kHz.

To make sure that Nyquist's theorem is satisfied, the input signal passes through an analog filter which attenuates all frequency components above 128 kHz by 90 dB. This is the anti-aliasing filter. The resulting digital time record is then mathematically transformed into a frequency spectrum using an algorithm known as the Fast Fourier Transform or FFT. The FFT is simply a clever set of operations which implements Fourier's basic theorem. The resulting spectrum shows the frequency components of the input signal. Now here's the interesting part. The original digital time record comes from discrete samples taken at the sampling rate. The corresponding FFT yields a spectrum with discrete frequency samples. In fact, the spectrum has half as many frequency points as there are time points. Suppose that you take 1024 samples at 256 kHz. It takes 4 ms to take this time record.

The FFT of this record yields 512 frequency points, but over what frequency range? The highest frequency will be determined by the period of 2 time samples or 128 kHz. The lowest frequency is just the period of the entire record or 1/(4 ms) or 250 Hz. Everything below 250 Hz is considered to be dc. The output spectrum thus represents the frequency range from dc to 128 kHz with points every 250 Hz.

The block diagram and topology of an FFT analyzer are different to that of the more usual superheterodyne or sweep spectrum analyzer. In particular circuitry is required to enable the digital to analogue conversion to be made, and then for processing the signal as a Fast Fourier Transform. The FFT spectrum analyzer can be considered to comprise of a number of different blocks:

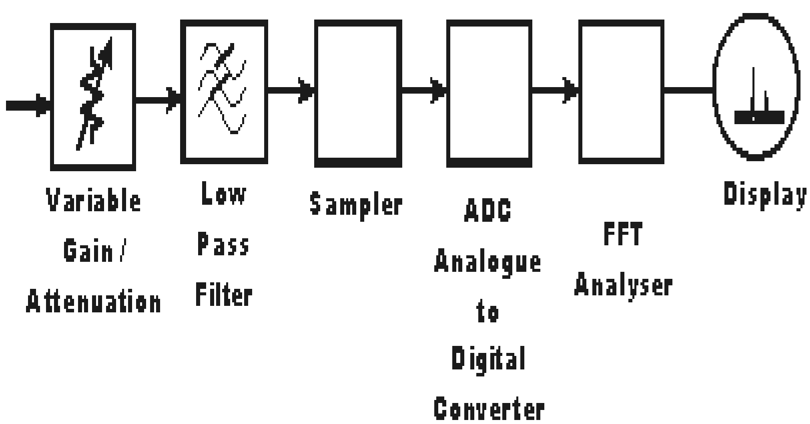

Fig. 5 FFT Spectrum Analyzer Block Diagram

- *Analogue front end attenuators / gain:* The test instrument requires attenuators of gain stages to ensure that the signal is at the right level for the analogue to digital conversion. If the signal level is too high, then clipping and distortion will occur, too low and the resolution of the ADC and noise become a problems. Matching the signal level to the ADC range ensures the optimum performance and maximizes the resolution of the ADC.

- *Analogue low pass anti-aliasing filter:* The signal is passed through an anti-aliasing filter. This is required because the rate at which points are taken by the sampling system within the FFT analyzer is particularly important. The waveform must be sampled at a sufficiently high rate. According to the Nyquist theorem a signal must be sampled at a rate equal to twice that of the highest frequency, and also any component whose frequency is higher than the Nyquist rate will appear in the measurement as a lower frequency component - a factor known as "aliasing". This results from the where the actual values of the higher rate fall when the samples are taken. To avoid aliasing a low pass filter is placed ahead

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

of the sampler to remove any unwanted high frequency elements. This filter must have a cut-off frequency which is less than half the sampling rate, although typically to provide some margin, the low pass filter cut-off frequency is at highest 2.5 times less than the sampling rate of the analyzer. In turn this determines the maximum frequency of operation of the overall FFT spectrum analyzer.

- *Sampling and analogue to digital conversion:* In order to perform the analogue to digital conversion, two elements are required. The first is a sampler which takes samples at discrete time intervals - the sampling rate. The importance of this rate has been discussed above. The samples are then passed to an analogue to digital converter which produces the digital format for the samples that is required for the FFT analysis.

- *FFT analyzer:* With the data from the sampler, which is in the time domain, this is then converted into the frequency domain by the FFT analyzer. This is then able to further process the data using digital signal processing techniques to analyze the data in the format required.

- *Display:* With the power of processing it is possible to present the information for display in a variety of ways. Today's displays are very flexible and enable the information to be presented in formats that are easy to comprehend and reveal a variety of facets of the signal. The display elements of the FFT spectrum analyzer are therefore very important so that the information captured and processed can be suitably presented for the user.

3.1 Advantages and disadvantages of FFT analyzer technology: As with any form of technology, FFT analyzers have their advantages and disadvantages:

<u>Advantages of FFT spectrum analyzer technology</u>

- *Fast capture of waveform:* In view of the fact that the waveform is analyzed digitally, the waveform can be captured in a relatively short time, and then the subsequently analyzed. This short capture time can have many advantages - it can allow for the capture of transients or short lived waveforms.
- *Able to capture non-repetitive events:* The short capture time means that the FFT analyzer can capture non-repetitive waveforms, giving them a capability not possible with other spectrum analyzers.
- *Able to analyze signal phase:* As part of the signal capture process, data is gained which can be processed to reveal the phase of signals.
- *Waveforms can be stored* Using FFT technology, it is possible to capture the waveform and analyze it later should this be required.

<u>Disadvantages of the FFT spectrum analyzer technology</u>

- *Frequency limitations:* The main limit of the frequency and bandwidth of FFT spectrum analyzers is the analogue to digital converter, ADC that is used to convert the analogue signal into a digital format. While technology is improving this component still places a major limitation on the upper frequency limits or the bandwidth if a down-conversion stage is used.
- *Cost:* The high level of performance required by the ADC means that this item is a very high cost item. In addition to all the other processing and display circuitry required, this results in the costs rising for these items.

3.2 Applications:

1) SIGVIEW is a real-time and offline signal analysis software package with wide range of powerful signal analysis tools, statistics functions and a comprehensive visualization system. SIGVIEW is one of the application of FFT analyzer.
2) It Provides tools for audio, sound and music. It calculates FFT (Fast Fourier Transform) of the sound.
3) It can perform RMS, Linear, Exponential and vector averaging.
4) Real time Bandwidth and Overlap Processing.
5) EMI Measurement Application.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 6, June 2013

REFERENCES

[1] Barnoski, M.K., Chen, B.U., Joseph, Thomas R., Lee, J. " Integrated-optic spectrum analyzer" circuits and systems, IEEE Transactions. Vol. 26, Issue No.12 **,** Dec 1979.

[2] Matthew T. Hunter , Achilleas G. Kourtellis, Christopher D. Ziomek, Wasfy B. Mikhael "Fundamentals of Modern Spectral Analysis" IEEE, 978-1-4244-7959-7/10, 2010.

[3] W. Lowdermilk, F. Harris, "Cost effective, versatile, high performance, spectral analysis in a synthetic instrument," in AUTOTESTCON, IEEE, pp. 148 –153, 2008.

[4] M. T. Hunter, W. B. Mikhael, and A. G. Kourtellis, "Wideband digital downconverters for synthetic instrumentation " IEEE Transactions Instrum. Meas., Vol. 58, no. 2, pp. 263–269, Feb. 2009.

[5] M. Hunter, A. Kourtellis, W. Mikhael, "Design of a software defined, fpga-based reconfigurable rf measuring receiver" AUTOTESTCON, IEEE, 14-17 2009, pp. 374 –379, 2009.

[6] P. Pragrastis, I. Sihra, M. N. Granieri, "Synthetic instrumentation: Contemporary architectures and applications (part ii)," RF DESIGN, pp.12–19, Nov. 2004.

[7] C. Rauscher, "Fundamentals of Spectrum Analysis", 6th ed. Rohde &Schwarz, 2008.

[8] "Ztec zt8441 rf/if digitizer," ZTEC Instruments, Jul. 2010. [Online]. Available: http://ztecinstruments.com/files/ LORF8441ALLInstruments. pdf.

BIOGRAPHY

Assistant Professor Mr. Sibu Thomas received MCA from Sikkim Manipal University, Manipal. He is having total teaching experiences of 13 years. His area of interest is .net technologies. He has published paper in 3 international journals and attended 1 international conference.

Nishi Shahnaj Haider obtained her Bachelor Degree BE (Hons.) in Electronics and Instrumentation and MTech. in Instrumentation and Control . She is currently with Bhilai Institute of Technology, Raipur, Chhattisgarh, India as Assistant Professor in Applied Electronics and Instrumentation Engineering Department. She had 3.8 years of teaching experience. Her areas of interest are microcontroller and instrumentation technologies. She has published 3paper in international journals and attended 1 international conference.