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Automatic Fine Tuning of Multichannel Front End Receiver

Navya P[1], MrinalSarvagya[2]

[1]*School of Electronics and Communication, REVA University (India)*

[2]*School of Electronics and Communication, REVA University (India)*

ABSTRACT

The RF Front End performs a greater improvement in sensing the spectrum in order to do better spectrum utilization. It mainly comprises of multiple channels of transmitters and receivers, control section and power section. It operates for wide bandwidth and also has capability of reconfiguration of its parameters. A multichannel Front End Receiver (FER) has two signals to be processed for the frequency mixing, a RF signal and a Local Oscillator (LO) signal which is tuned for multiple frequency values for each channel. In order to tune for multiple frequencies and obtain multiple IF (Intermediate Frequency) outputs for three different channels (sum, azimuth and elevation), the three channels are operated depending on their gain and down conversion. Manually operating the instruments (RF input device, local oscillator, spectrum analyzer and power supply) of a FER for multiple frequencies will become tedious, and testing of the front end receiver will be hectic and very time consuming. It will also incur more errors and offer less accuracy. This paper aims to increase the efficiency of the system and reduction of time conservation for testing of the Front End Receivers. Thus this process of testing the Front End Receiver for multiple frequencies can be automated by using a software approach for tuning multiple channels, the devices and the instruments are interfaced with the PC. The proposed design has been simulated with MATLAB by using VISA for interfacing the devices with the PC. Its Graphical User Interface is created for the corresponding automation code. From the simulation results it can be derived that the proposed automatic fine tuning of FER is 69 settings lesser than the manual testing approach. The time conservation has also been reduced by 84%. The error analysis report for manual testing and automatic testing is done. Therefore, the proposed automatic fine tuning is said to be more efficient.

Keywords:FER, spectrum, frequency tuning, gain, down conversion

I. INTRODUCTION

In a radio receiver circuit the RF front end is said to be the collective term for the circuitry between a receiver's antenna inputs up to the mixer stage. It includes all the components in the receiver that is responsible for

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processing the signal at the original incoming radiofrequency (RF) in prior conversion to a lower intermediate frequency (IF).

A superheterodyne receiver converts the RF to IF which can be more conveniently processed than the original carrier frequency.

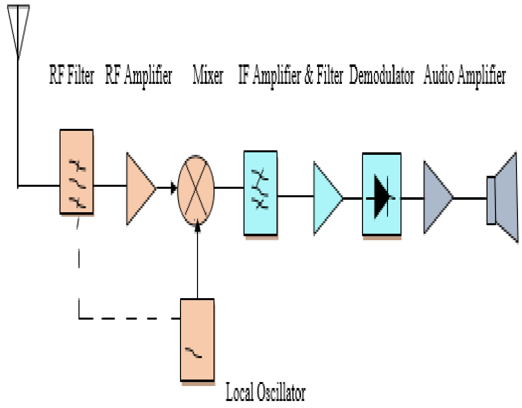

Fig1: Typical superheterodyne receiver

The pink blocks processes the original Radio frequency signals, and the blue blocks performs operation of modulated intermediate frequency signals.

The antenna collects the Radio signal, the initial selectivity is provided by the RF amplifier. The frequency mixer performs the heterodyning, hence called superheterodyne. The frequency mixer is provided with the amplified RF input and local oscillator signal, thus, producing an IF signal. Then, the IF signal is amplified and demodulated output is provided to the audio amplifier.

For most super heterodyne architectures, the RF front end consists of

- A band-pass filter(BPF) for reducing the image response which removes signals at the image frequency that would interfere with the desired signal. The strong out-of-band signals from saturating the input stages are prevented.
- An RF amplifier, which is also often called the low-noise amplifier (LNA). Its primary responsibility is to increase the sensitivity of the receiver, sensitivity can be increased by amplifying the weak signals without contaminating them with noise and it must have a very low noise figure (NF). For frequencies below 30 MHz RF amplifier may not be needed and is often omitted (or switched off).
- A radio frequency signal at an offset from the incoming signal is generated by the local oscillator (LO) and LO is mixed with the incoming signal.
- The mixermixes the incoming signal with the local oscillator signal to convert the signal to the intermediate frequency (IF).

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In digital receivers, such as cell phones and Wifi receivers that are wireless devices, the intermediate frequency is digitized; sampled and converted to a binary digital form, and the rest of the processing - IF filtering and demodulation - is done by digital filters.

The term Automatic Test Equipment (ATE) encompasses all phases of computer controlled testing. It is based on the integration of instruments, computers and software. These systems generally include five basic elements: control, stimulus, measurement, switching and software [1]. Several test methods have been developed to troubleshoot and test subarrays. The test apparatus is portable and therefore can be employed in the laboratory or in the field. By utilizing a desktop computer, the test engineer can fully automate the subarray testing and reduce test time and labour by an order of magnitude [2]. System calibration is carried out in the network analyzer to mitigate losses in the input and output paths [3].The test engineer can fullyautomate the subarray testing and reduce test time and laborby **an** order of magnitude[4]. Front End module is measured with and without antenna for obtaining the results like gain, harmonics, spurious, flatness, amplitude ripple, cross coupling, AGC dynamic range [5]. VISA defines an application interface for devices communicating via GPIB, RS232, USB, Ethernet, PXI and VXI interface [6]. Modern day ATE systems and software offer the ability to verify a product's functionality and provide pass / fail test results [7].

The testing of the FER can be done manually by connecting all the input and output instruments to the Front end Receiver. The input frequency value and LO values are set using a signal generator. Thus output power is obtained for each RF signal and LO signal and thus the gain can be calculated by using equation (1).

$$\text{Gain (dBm)} = \text{output power} - \text{input power} \tag{1}$$

II. PROPOSED WORK

The manual testing of Front End Receiver is said to be erroneous, enormous time consuming and tedious process. Therefore there arises a need to make itautomated by using a software approach for the fine tuning. For automatic fine tuning of the multichannel Front End Receiver, the testing can be perceived using a MATLAB code. The MATLAB has got the capabilities of interfacing all the instruments using Virtual Instrument Software Architecture (VISA), which provides interface between the hardware and the software. The VISA uses the Standard Commands for Programmable Instruments which provides the standard syntax, command structure and data interchange format being used for the test instruments. After the program code is compiled and simulated, the measured power and gain values for each frequency value for multiple channels (sum, azimuth and elevation) is stored in the report. The report can be viewed by designing a Graphical User Interface, which allows the user to interact with instruments through graphical icons and visual indicators such as secondary notation, instead of text-based user interfaces, typed command labels or text navigation.

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A.Design of Front End Receiver

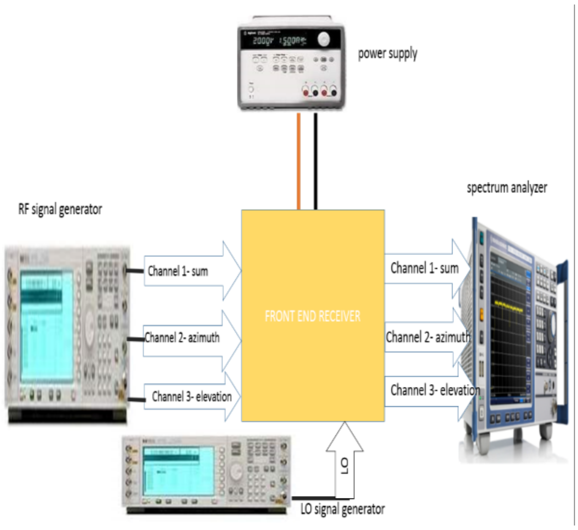

Fig2: design of Front End Receiver

The above proposed automatic fine tuning of the Front End Receiver has multiple channels such as Channel 1 – Sum, Channel 2- Azimuth and Channel 3- Elevation , where RF signal generator and Lo signal generator has to be tuned to 10 different frequencies for each channel, the output is observed in the output device, spectrum analyzer. The output of FER also consists of multiple channels, named as Channel 1- Sum, Channel 3- azimuth and Channel 3- elevation, the corresponding output measurements has to be recorded Thus automatic fine tuning using MATLAB is done and complied, the result is stored in the .txt format and .xls format for the report analysis of that FER.This process of automation reduces the manual frequency tuning settings by the user by using the program code for the testing.

B. *Graphical User Interface Module*

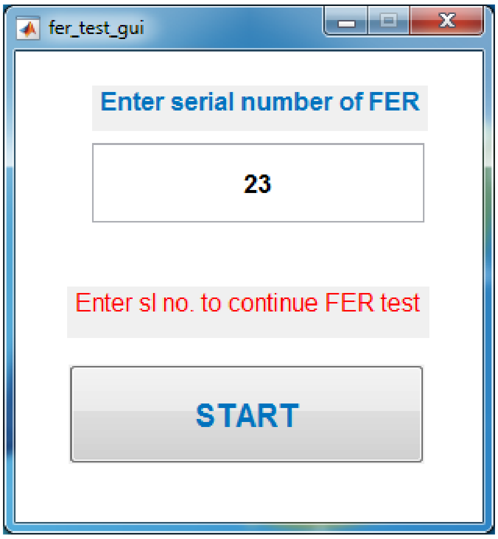

Fig3: Graphical User Interface module

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III. TEST RESULTS

Reports are in two different formats:

A. Text format (.txt)

B. Excel format (.xls)

A. Text format (.txt)

FER Serial No. is: 23 27-Nov-2018 13:06:41		
Current drawn by FER: 1.30		
FER testing for channel: 1		
Sl no	IF_freq(Mhz)	Gain(dBm)
1	75.00	42.39
2	75.00	42.47
3	75.00	42.57
4	75.00	42.14
5	75.00	42.05
6	75.00	42.77
7	75.00	42.63
8	75.00	42.57
9	75.00	43.08
10	75.00	43.31

FER testing for channel: 2		
Sl no	IF_freq(Mhz)	Gain(dBm)
1	75.00	40.48
2	75.00	40.74
3	75.00	40.52
4	75.00	39.90
5	75.00	40.18
6	75.00	40.97
7	75.00	40.31
8	75.00	40.25
9	75.00	41.15
10	75.00	41.25

FER testing for channel: 3		
Sl no	IF_freq(Mhz)	Gain(dBm)
1	75.00	42.16
2	75.00	42.39
3	75.00	42.04
4	75.00	41.48
5	75.00	41.81
6	75.00	42.46
7	75.00	41.70
8	75.00	41.74
9	75.00	42.69
10	75.00	42.64

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B. Excel format (.xls)

FER SERIAL NO. : 23							
CURRENT DRAWN BY FER : 1.30							
FREQ	INPUT (dB	SUM IF (dI	AZ IF (dBn	EL IF (dBm	GAIN SUM	GAIN AZ	GAIN EL
LFC1	-42.94	-0.55	-2.46	-0.78	42.39	40.48	42.16
LFC2	-42.8	-0.33	-2.06	-0.41	42.47	40.74	42.39
LFC3	-42.61	-0.04	-2.09	-0.57	42.57	40.52	42.04
LFC4	-42.57	-0.43	-2.67	-1.09	42.14	39.9	41.48
LFC5	-42.7	-0.65	-2.52	-0.89	42.05	40.18	41.81
LFC6	-42.94	-0.17	-1.97	-0.48	42.77	40.97	42.46
LFC7	-42.61	0.02	-2.3	-0.91	42.63	40.31	41.7
LFC8	-43.03	-0.46	-2.78	-1.29	42.57	40.25	41.74
LFC9	-43.58	-0.5	-2.43	-0.89	43.08	41.15	42.69
LFC10	-43.31	0	-2.06	-0.67	43.31	41.25	42.64

IV. PERFORMANCE EVALUATION

The manual testing of the Front End Receiver includes multiple steps for tuning the instruments. Hence the total number of steps is shown in the below table.

Instruments	**No. of Steps for manual testing of FER**	**No. of Steps for automatic testing of FER**
Power Supply	Switch on Voltage set Current set Switch off	Switch on Switch off
RF Signal Generator	Switch on Frequency set (30 times) Amplitude set RF ON Switch off	Switch on Switch off
LO	Switch on	Switch on

Signal Generator	Frequency set (30 times) Amplitude set RF ON Switch off	Switch off
Spectrum Analyzer	Switch on Center frequency set Peak search Reference level set Switch off	Switch on Switch off
Total no. of steps	77	8

Table1: total steps for testing

Hence automatic fine tuning of multichannel FER is reduced by 69 steps, this in turn reduces the time conservation and also provides accurate report analysis. Also reduces the power consumption for all the devices as the speed of operation is faster than manual testing.

V. CONCLUSION AND FUTURE WORK

Manual systems tend to put pressure on people to be perfect in all the aspects of the work, inculcating each and every details of their work with neat precision. But the general consensus entails that people aren't perfect to a good extent, however much each of us try. With manual systems the level of service is said to be dependent on individuals and hence giving rise to human errors while tuning the instruments as well as while recording the report manually. Reporting and checking that data is robust can be timely and expensive.

Test automation increases the overall software efficiency and ensures robust software quality. There are specific tools that can effectively execute automated test cases, and help in comparing actual and expected results. In this manner, automated testing can guarantee software proficiency without involving repeated and manual intervention. Automation also reduces the time requirement for testing the devices as 69manual steps can be done by a single click on the GUI using the automation. This tremendously diminishes requirement of human capital and their dependencies, thus, deemed to be accurateand efficient as recording of the output is carried out by the system itself, in turn reducing the cost and power consumption for the testing, as testing is done at a faster rate.

The manual testing and tuning of the multichannel FER requires 77 settings to be done manually and which also increases the FER testing time and also leads to increase in the power consumption. The manual report or

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document can consist of human errors as human beings are not perfect, the approximated time for manual testing for 3 channel Front End Receiver is approximated as 18 minutes.

The automatic fine tuning system can overcome all the above disadvantages, it requires only 8 settings(switching on and off of all the devices) for the entire testing of the FER and where the power consumption is being reduced at a greater extent as the testing is done at a faster rate, approximately 3minutes. The efficiency of the automatic testing is increased by 84% than the conventional manual testing of the FER. The reports are recorded by the system itself hence reducing the human errors during the recording of the output values.

As the GUI is built, the entire process of testing can be done by clicking on the 'START' button provided on the GUI. By adopting the Automatic fine tuning, the FER systems with more channels and which require more frequency tuning capabilities provides a greater advantage. The system can be fully automated by using switches for the channel selection and a complete ATE can be realized.

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