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Advance LabVIEW Application for Accurate and Precise RF Attenuation Measurement with Improved Uncertainty

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Abstract: In the present paper an automated version of well established 30 MHz IF (intermediate frequency) substitution technique based on LabVIEW platform has been developed, used for measuring RF attenuation. A detailed software implementation and hardware synchronization with developed software is elaborated with user defined GUI on LabVIEW platform. A complete set of measurement have been performed and for the authenticity of the measured results, the data have been compared with the manual measurement data. Not only the results found in good agreement but the expanded uncertainty also improved (attenuation 0dB- 60 dB and frequency 30MHz- 15 GHz). The automated experimental setup is three times faster than the manual measurement with a significant improvement in the uncertainty in measurements.

Introduction

As the scope for instrument control using the National Instruments (NI) LabVIEW is increasing, engineers are relying more on LabVIEW applications for complete control of instruments over a personal computer (PC) but inadvertently the readability and scalability of the graphical code of LabVIEW degrades with the increasing size of the applications. Hence, it is essential to incorporate software engineering paradigms while developing LabVIEW applications. LabVIEW is a graphical language based on dataflow paradigm, which keeps on adding new functionalities with every new release. However, with the software engineering guidelines and toolkits provided by the LabVIEW, it is easier to develop more accurate and validated applications with reduced development time. However, while reworking on the LabVIEW code, it is always felt that it should be more organized and readable, that is why it will be a good practice to have software engineering paradigms included.

In present endeavor, a LabVIEW application for RF attenuation measurement, implementing 30MHz Intermediate Frequency (IF) Substitution Technique have been developed. During the development of the application, it was easy to code the program but while reworking on the code for additional functionalities it was felt that the code should be more readable, optimized and that the application needs to be completely re-factored according to the software engineering practices. The software discussed here acquires the result of the calibration of the attenuator and is re-factored according to software engineering guidelines in order to get a cleaner code.

1. Measurement Technique

In the IF substitution technique, a mixer along with an IF receiver is introduced into the measurement system to generate the desired IF frequency (Fig. 1). To perform this substitution method two different RF sources are required. A mixer with calculated non-linearity is deployed between the RF source and Local oscillator. The mixer is a three-port device, two RF source will act as an input of the mixer, and the difference between these frequencies will generate an intermediate frequency from the output port [1-2].

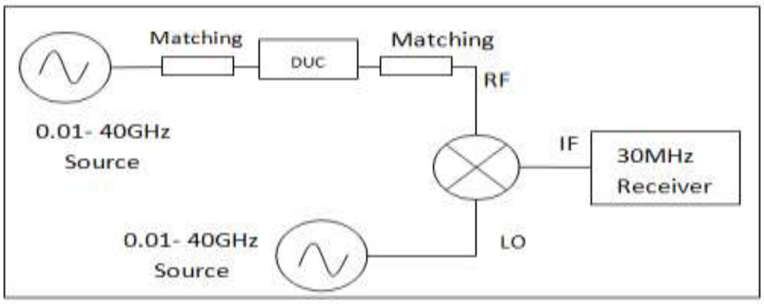


Fig. 1: Block Diagram of 30MHz IF Substitution Technique

Fig. 2: Measurement Setup of 30MHz IF Substitution Technique

In the measurement, 30 MHz substitution technique [1-2] is deployed because of the 30 MHz receiver (VM7), shown in Fig. 2. VM7 is a 30 MHz tuned receiver with in-built local oscillator. Both LO and 30 MHz receiver can be controlled by the software. The LabVIEW application is developed in such a way that VM7 is automated in synchronization with other instruments.

2. System Introduction

2.1 LabVIEW Application- LabVIEW is a graphical programming language consisting of a block diagram and a front panel, which acts as a Graphical User Interface (GUI). The block diagram and front panel forms a program in LabVIEW called Virtual Instrument (VI).

2.2 System Hardware- The system for attenuation measurement consist of a RF signal generator (SMR 40) [3], a 30MHz tuned receiver (VM7) and for instrument control a PC installed with LabVIEW. An attenuator driver is also used to drive the step attenuator [4]. GPIB card is connected with the instruments to be controlled programmatically, which provides a GPIB-USB handshake between the PC and the instrument.

3. Measurement Interface

3.1 GUI for Attenuation Measurement- The front panel for the application, shown in Fig. 3, provides the control to the end user to enter the measurement specifications viz. number of readings, repetition of the experiment, system stabilization and time delay etc. The required settings are fetched from the excel sheet whose path is given by the user and the corresponding readings at different levels and frequencies are displayed accordingly on the front panel at the real time. By default, an additional excel sheet will be created automatically at the end of the process to log the read data.

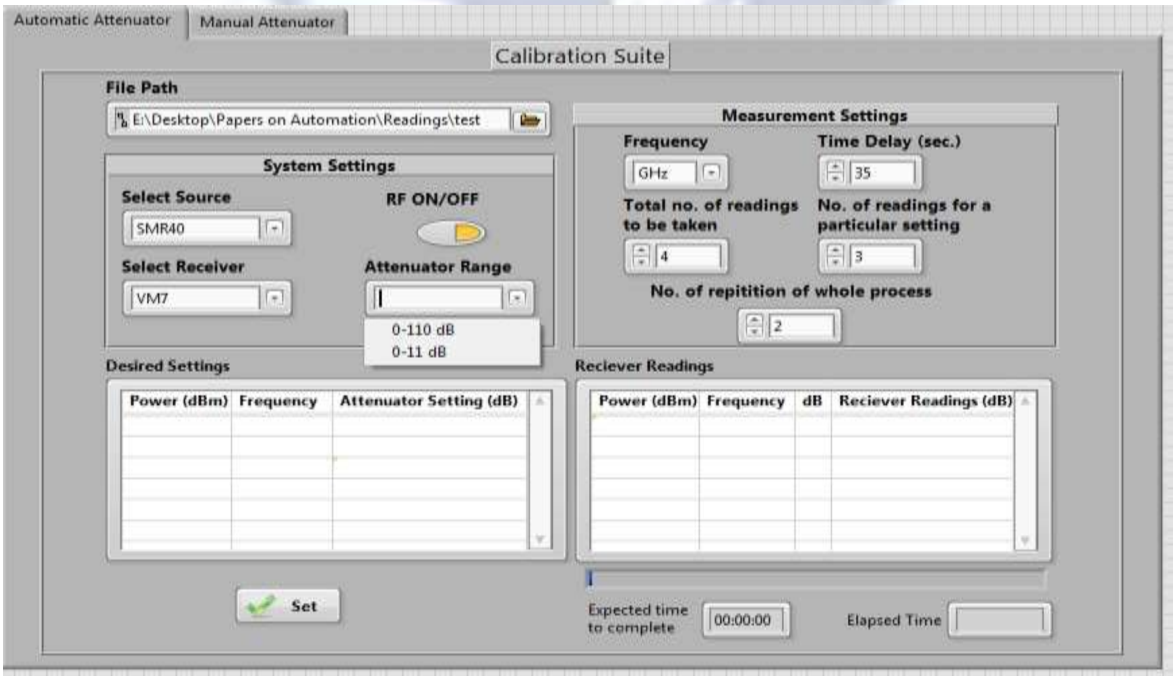


Fig. 3: Front Panel of the automation software in LabVIEW

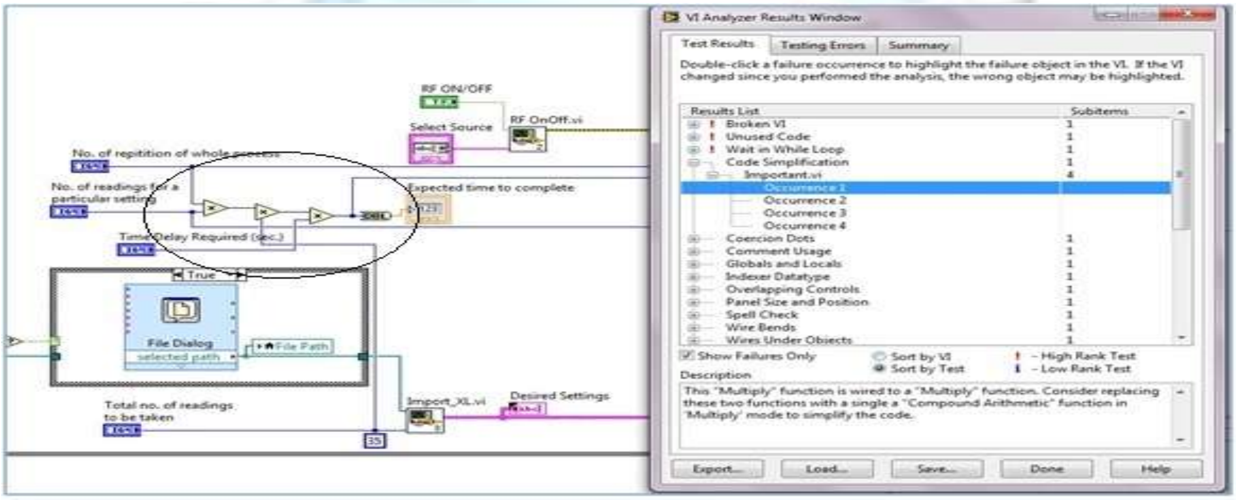
3.2 Block Diagram of Application- Table I lists the main functions used in the block diagram.

Table I: Main LabVIEW Functions

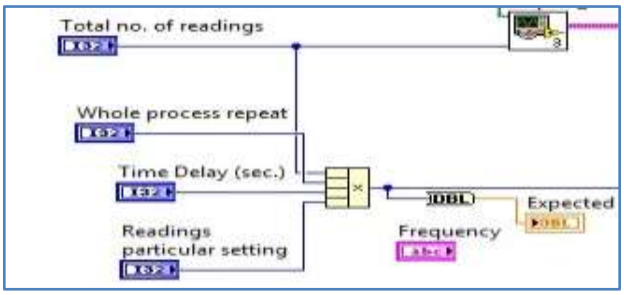
Palette	Sub-Palette	Function	Used for
Instrument I/O	GPIB	GPIB Read and Write	Instrument Control GPIB Read- Reading instrument result (output) buffer GPIB Write- Sending query to the instrument
Programming	Structures	For Loop and While Loop	Iteration/ Repetition
	Dialog and User Interface	File and Message Dialog	User friendly GUI
	Timing	Elapsed Time	Progress Bar
	Array	Array Size, Index Array, Insert into Array, etc	Data Management

4. Software Engineering and LabVIEW

There are a number of toolkits provided by NI for implementing automated software engineering phases. For refactoring our application to have a cleaner graphical code, the main toolkits we used upon the code are Unit Test Framework and VI Analyzer. These toolkits automate the validation phase of the software engineering model. The software application can be put under the unit testing with the LabVIEW Unit Test Framework toolkit in which test cases are run. Similarly, VI Analyzer is used for code review; an instance is shown in Fig.4.



(a)



(b)

Fig. 4. (a) VI Analyzer Results. An example of code simplification is shown in the diagram though the VI Analyzer applies a number of tests such as complexity metrics, VI metrics, VI properties, etc which includes errors as minute as spelling errors. (b) Simplified code example

5. Uncertainty Evaluation

Key sources of uncertainties were identified and listed below in a tabulated format along with their probability distributions and limits [5].

Table II. Sources of Uncertainty with their Probability Distribution

Sources of Uncertainty	Limits (±dB)	Probability Distribution
Repeatability, U_A	0.00837	Normal
Standard Attenuator, U_{B1}	0.04	Normal
Meter Resolution, U_{B2}	0.005	Rectangular
Mismatch Uncertainty, U_{B3}	0.00682	U-shaped
Mixer Nonlinearity, U_{B4}	0.0602	Rectangular
Isolation, U_{B5}	0.0282	Rectangular
Combined Uncertainty, U_C		
Expanded Uncertainty, U		*k*≈2

Combined uncertainty (*Uc*) cab be defined as:

$$U_C = \sqrt{{U_A}^2 + {U_{B1}}^2 + {U_{B2}}^2 + {U_{B3}}^2 + {U_{B4}}^2 + {U_{B5}}^2} \quad (1)$$

Similarly, Expanded Uncertainty (U) = *k* x *Uc* (2)

k is calculate from student's t- distribution.

6. Measurement Results and Comparison

The prime expectations from an automated system are reduced experimentation time and accurate data acquisition with reduced uncertainty. The results are shown in Fig. 5 for attenuation level 0-60dB at various frequencies acquired from manual and automated system. Uncertainty values have been calculated from Table II, for both measurements. The comparison shows that there is a significant improvement in the uncertainty, with the use of the automated system, the time for the measurement procedure is drastically reduced. The automated system takes hardly 3 ½ hour to compute the entire measurement with minimum ten observations for each frequency and each step of attenuation. Manually it will take minimum one working day (10 hour) to complete 450 observations with 30 seconds system stability time for each observation (Fig. 6).

Additionally, another comparison is made between the general and the optimized code. It is to be understood that both the codes works with same efficiency but the optimized code is just for better understandability, shown in Fig.7. The repeatability (U_A) of the measurement is the key source of error in uncertainty evaluation hence the effect of automation is studied on U_A also. From Table III it is interesting to note that U_A improves in more than 65% automated measurement data over manual one. Table III clearly shows that the automated system provides better uncertainty at critical points especially at higher level of attenuation.

The same can be drawn from Fig. 5. It can also be concluded from Fig. 5 that the difference between manual and automated system ceases to exist at 60 dB attenuation. The accuracy of the automated system is almost directly proportional to the attenuation value. The same pattern follows in case of frequency also i.e. the automated results improve with increasing frequency. A technical comparison has been carried out on three key parameters viz. measured values, uncertainty estimation and evaluation time. It is obvious to say that automated 30 MHz IF substitution is more accurate, precise and time saver than manual system.

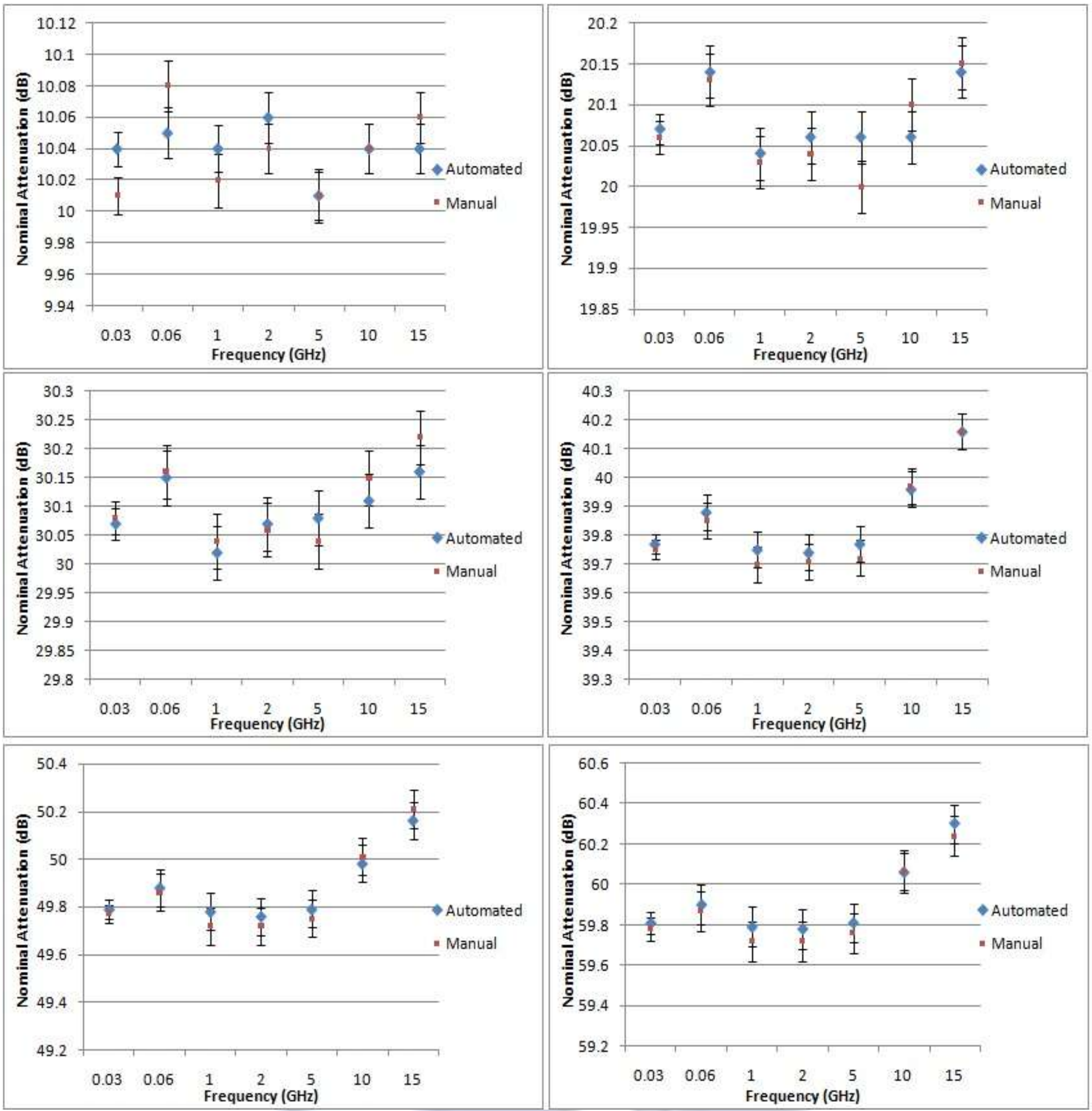


Fig. 5: Measurement Results

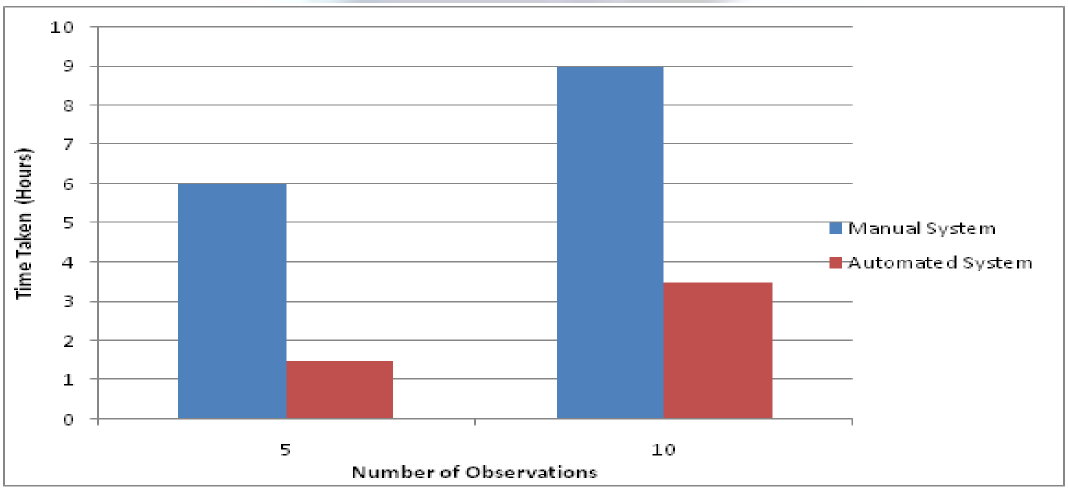


Fig. 6: Comparison of manual and automated measurement on time scale

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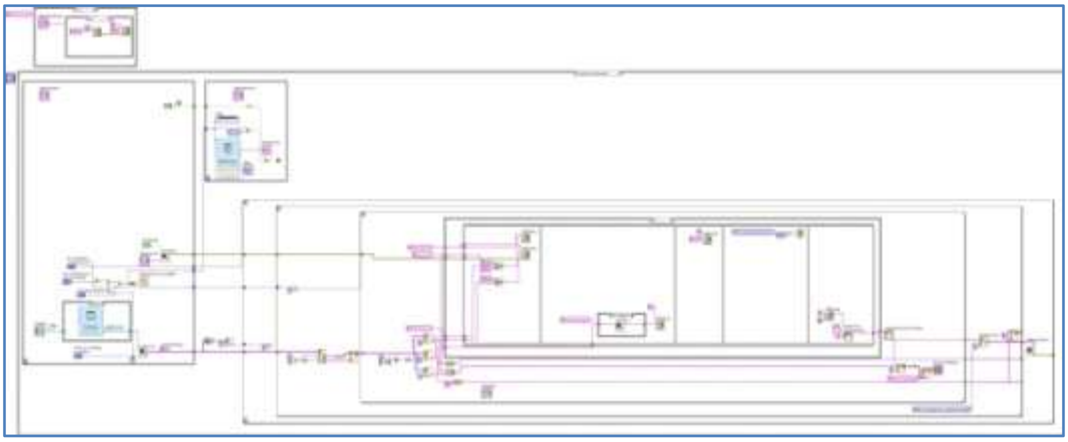

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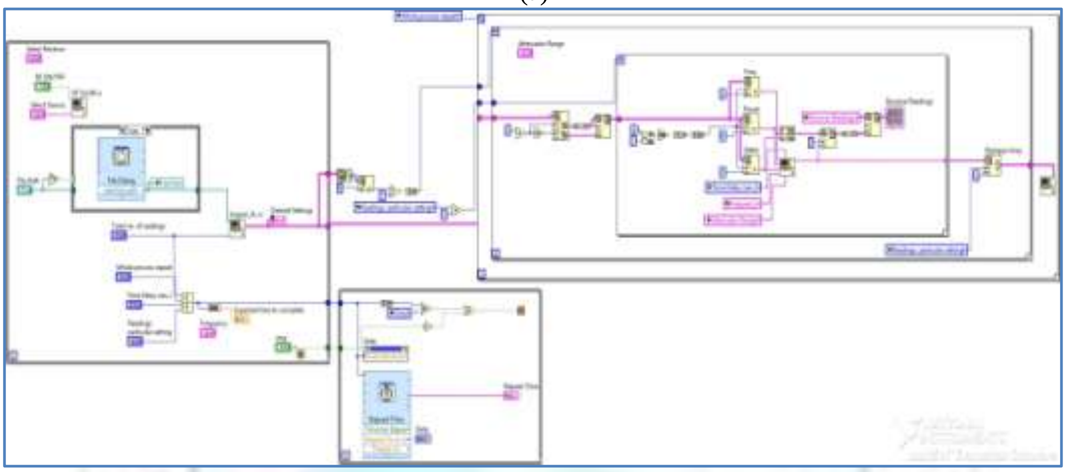

(b)

Fig. 7: (a) Primitive code that is less readable. (b) Final optimized code

Table III. Comparison of Automated and Manual Results

Frequency (GHz)	Measured Attenuation (dB)	Manual Type-A Uncertainty $\pm U_{Am}$	Automated Type-A Uncertainty $\pm U_{Aa}$	Manual Expanded Uncertainty $\pm U_{Cm}$	Automated Expanded Uncertainty U_{Ca}	Difference (U_{Am}-U_{Aa})
0.30	10	0.003	0.002	0.012	0.011	0.001
	20	0.000	0.000	0.020	0.019	0.000
	30	0.002	0.003	0.028	0.028	-0.001
	40	0.000	0.002	0.033	0.032	-0.002
	50	0.003	0.002	0.039	0.037	0.001
	60	0.000	0.001	0.056	0.054	-0.001
0.60	10	0.003	0.001	0.010	0.011	0.002
	20	0.002	0.003	0.021	0.019	-0.001
	30	0.000	0.000	0.030	0.028	0.000
	40	0.002	0.000	0.040	0.032	0.002
	50	0.000	0.000	0.052	0.050	0.000
	60	0.000	0.000	0.060	0.054	0.000
1	10	0.005	0.000	0.014	0.011	0.005
	20	0.000	0.001	0.022	0.019	-0.001
	30	0.002	0.000	0.031	0.028	0.002
	40	0.002	0.001	0.041	0.032	0.001
	50	0.003	0.001	0.052	0.049	0.002
	60	0.003	0.000	0.068	0.054	0.003
2	10	0.002	0.000	0.011	0.011	0.002
	20	0.002	0.001	0.022	0.019	0.001
	30	0.000	0.000	0.031	0.028	0.000
	40	0.000	0.001	0.041	0.032	-0.001

	50	0.000	0.001	0.052	0.050	-0.001
	60	0.000	0.000	0.068	0.054	0.000
5	10	0.002	0.000	0.013	0.011	0.002
	20	0.000	0.001	0.022	0.019	-0.001
	30	0.000	0.000	0.033	0.028	0.000
	40	0.002	0.001	0.042	0.032	0.001
	50	0.000	0.001	0.052	0.051	-0.001
	60	0.002	0.000	0.068	0.054	0.002
10	10	0.001	0.000	0.011	0.011	0.001
	20	0.000	0.001	0.022	0.019	-0.001
	30	0.002	0.000	0.032	0.028	0.002
	40	0.000	0.001	0.041	0.040	-0.001
	50	0.000	0.001	0.052	0.050	-0.001
	60	0.000	0.000	0.069	0.054	0.000
15	10	0.002	0.000	0.013	0.012	0.002
	20	0.000	0.001	0.022	0.023	-0.001
	30	0.000	0.000	0.033	0.032	0.000
	40	0.002	0.001	0.042	0.045	0.001
	50	0.000	0.001	0.052	0.051	-0.001
	60	0.005	0.000	0.069	0.068	0.005

Conclusion

The automated software in LabVIEW is created for 30 MHz IF substitution attenuation measurements and then optimized for better readability of the graphical code. The results of the attenuation measurement from both manual and automated system are presented with their corresponding uncertainties. All the measured attenuation along with their uncertainties is in good agreement to the manual results and there is an improvement in the results at higher attenuation and frequency over the manual one. The automated system is three times faster than the manual system.

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