# Radar Pulse Generation Example

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***Abstract*:- This document provides a brief description of the Radar Pulse Generation Functionalities and instructions to operate the UI Radar Signal Generation Example Instructions Manual**

## OVERVIEW

This example is a generic demonstration for radar pulsed modulated signals. It provides the ability to configure different pulse modulation and play the signal via a Vector Signal Generator or Transceiver using the RFSG driver.

Supported Modulations:

This example supports the generation of the following signals:

1- **Unmodulated pulse:** A standard pulse with configurable duty cycle (duration) and IQ rate
2- **FM Slow Chirp:** A LFM modulated signal with an up-ramp and down-ramp and configurable chirp length or ratio (ratio of the entire pulse duration)
3- **FM Fast Chirp**: A LFM modulated signal with a configurable number of up-chirps where the pulse duration is
4- spread evenly over the
5- configured number of chirps

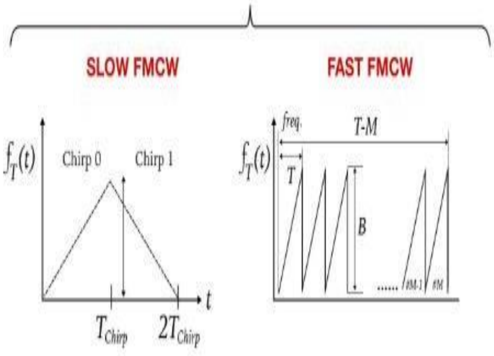


*Figure 1: FMCW Definition (source: Texas Instruments)*

6- **Non Linear FM (NLFM**) :A Nonlinear FM compressed pulse with configurable exponential order
7- **Barker Coded BPSK:** Phase-coded waveforms differ from FM waveforms in that the long pulse is sub-divided into a number of shorter sub pulses. Generally, each sub pulse corresponds with a range bin. The sub pulses are of equal time duration; each is transmitted with a particular phase. The phase of each sub-pulse is selected in accordance with a phase code. The most widely used type of phase coding is binary coding.

The binary code consists of a sequence of either +1 and -1. The phase of the transmitted signal alternates between 0 and 180° in accordance with the sequence of elements, in the phase code, as shown on the figure. Since the transmitted frequency is usually not a multiple of the reciprocal of the sub-pulse width, the coded signal is generally discontinuous at the phase-reversal points.

The selection of the so-called random 0, π phases is in fact critical. A special class of binary codes is the optimum, or Barker, codes. They are optimum in the sense that they provide low sidelobes, which are all of equal magnitude. Only a small number of these optimum codes exist. They are shown on the beside table. A computer based study searched for Barker codes up to 6000, and obtained only 13 as the maximum value.

It will be noted that there are none greater than 13 which implies a maximum compression ratio of 13, which is rather low.

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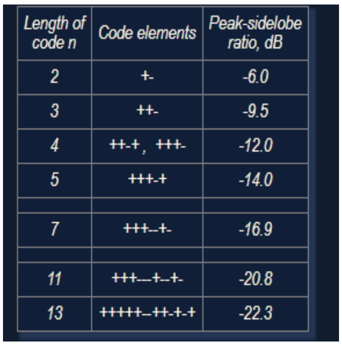
Figure 2: Barker Codes *(source: radartutorial.eu)*



| Length of code n | Code elements | Peak-sidelobe ratio, dB |
|---|---|---|
| 2 | +- | -6.0 |
| 3 | ++- | -9.5 |
| 4 | ++-+, +++- | -12.0 |
| 5 | +++-+ | -14.0 |
| 7 | +++--+- | -16.9 |
| 11 | +++---+--+- | -20.8 |
| 13 | +++++--++-+-+ | -22.3 |

UI Configurable Options :

The UI consists of 4 main sections:

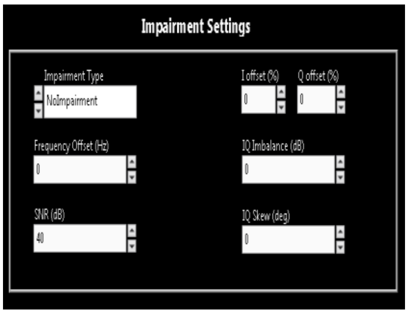
1. Signal Settings

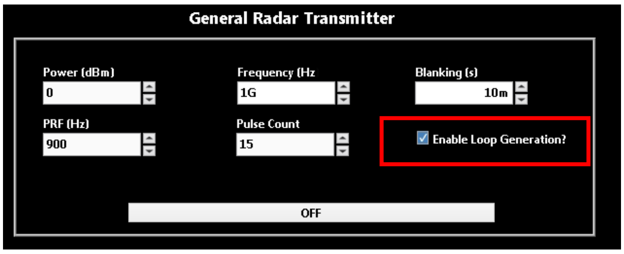
This section allows custom configuration of pulsed modulated signal including:

- Selected pulse modulation
- Modulation specific parameters such as pulse duration, IQ rate, BW, ratio, order…

| Modulation | Available Configurable options | Description |
|---|---|---|
| Unmodulated Pulse | Duration | Pulse Width |
| | IQ Rate | Signal IQ rate, must be > 2*(1/pulse length), in this example a ratio of 5 to 7 is considered |
| | Zero Waveform | Set the pulse to Zero, can be used for blanking |
| FM Slow Chirp | IQ Rate | Signal IQ rate, must be > 2*(1/pulse length), in this example a ratio of 5 to 7 is considered |
| | BW | Ramp BW |
| | Duration | Pulse duration |
| | Chirp Ratio | Percentage of chirp from pulse width |
| | Direction | Start with up-ramp followed by down-ramp or vice versa |
| FM Fast Chirp | IQ Rate | Signal IQ rate, must be > 2*(1/pulse length), in this example a ratio of 5 to 7 is considered |

- Impairment Settings: Different types including AWGN, Vertical and horizontal impairments or No impairments applied. You can add more than on type of impairment per signal.



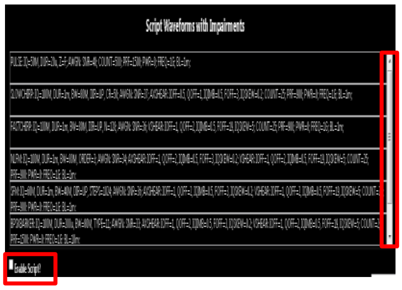

2. General Radar Transmitter Settings

This section includes the following settings

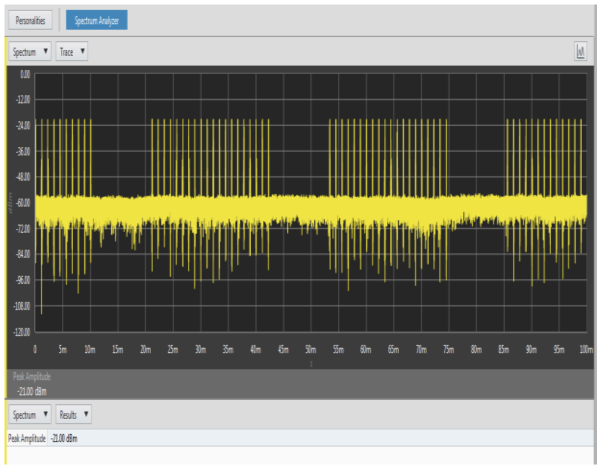
- Power: the signal transmitted power which is a setting of the VST Tx port
- PRF: Which is the pulse frequency (pulse repetition rate)
- Frequency: This is the carrier frequency which is a property of the VST Tx port


| | | |
|---|---|---|
| | BW | Ramp BW |
| | Duration | Pulse duration |
| | Chirp number | Number of chirps in the pulse, chirp duration is pulse duration divided by #chirps |
| | Direction | Slope direction |
| NLFM | IQ Rate | Signal IQ rate, must be > 2*(1/pulse length), in this example a ratio of 5 to 7 is considered |
| | BW | FM Deviation |
| | Duration | Pulse duration |
| | order | Exponential |
| Barker Coded BPSK | IQ Rate | Signal IQ rate |
| | BW | 1.25*BW < IQ rate <= 2.5*BW |
| | Duration | Pulse Width |
| | Barker Type | Barker code 2 to 13 |
| | | |

- Pulse Count: This option allows configuration of Pulse train. The count represents the number of consecutive pulses distant relatively to the configured PRF




- Blanking: This option allows blanking between different generated pulse trains, where you configure the desired blanking time in sec
- Enable Loop Generation: This option allows looping over the pulse train configured until the application is stopped. The results would look as following




3. Script Waveforms with Impairments Configuration

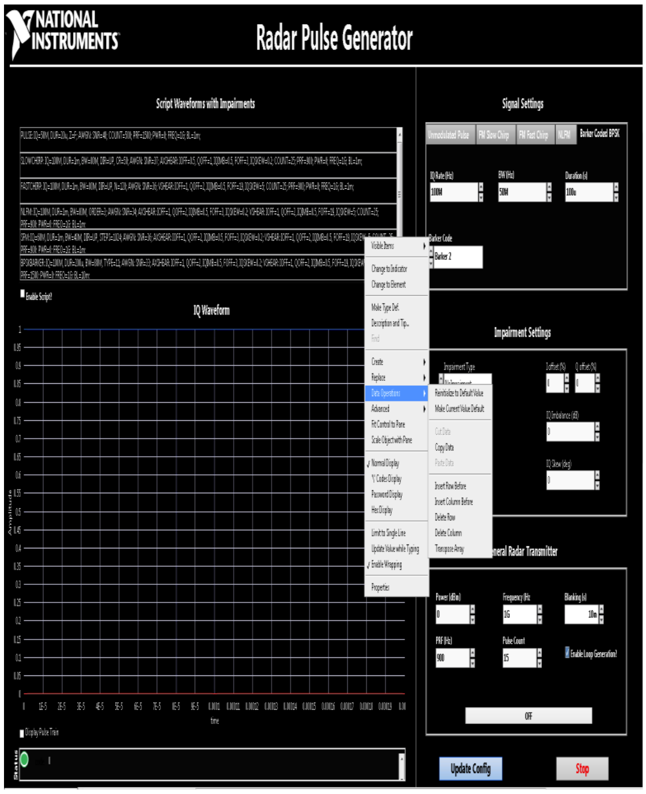
This section allows generation of a sequence of pre-configured signals. The table contains multiple rows where each row defines a pulsed signal with its required parameters and added impairments

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Modulation_type | : | space | Param1 | = | Param1_value | , | space | Param2 | = | Param2_value | , | space | ... | ; |

The configuration is as following

To enable scripting, you must click on **Enable Script?** This will run the sequence row by row and then loop back if the Enable Loop Generation is enabled. This option will also disable the manual Signal Generation You can modify the parameters in the script, add or delete. To Add, scroll down the table using the scrollbar to the right side, this will show an empty row where you can start typing given the above configuration.

To insert a row between 2 others, right click a given row then click on **Data Operations >> Insert Row Before**




To make it easy, a Script assistant is available to help you configure the table interactively, add, delete rows, as well save your configuration to a file or load it from an existent file.

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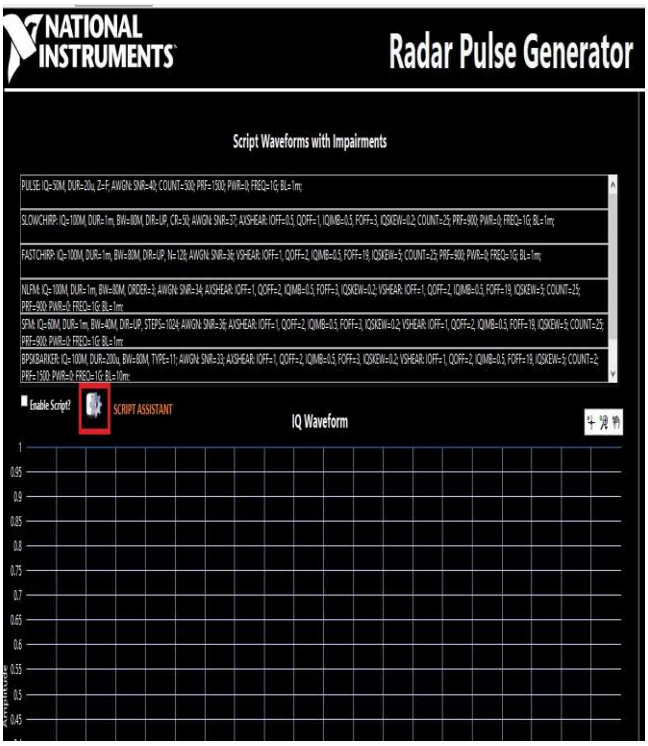
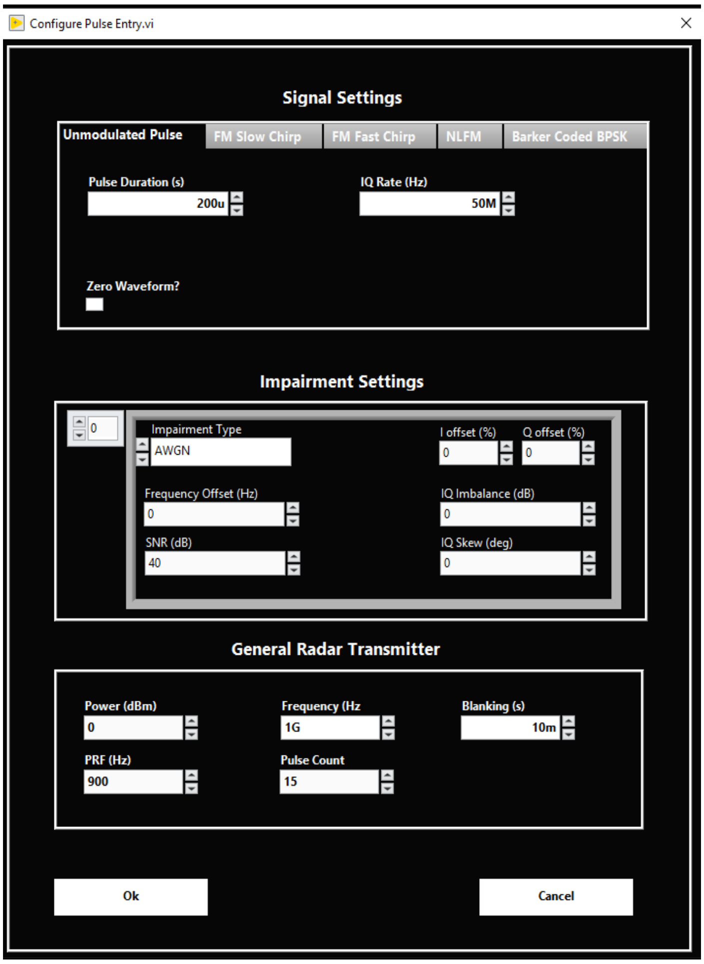
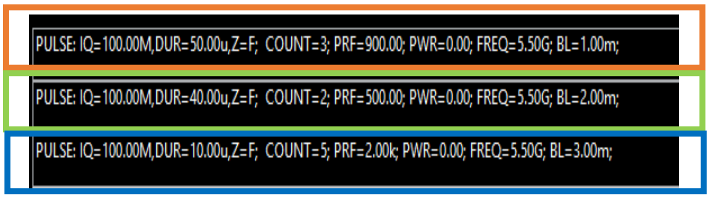


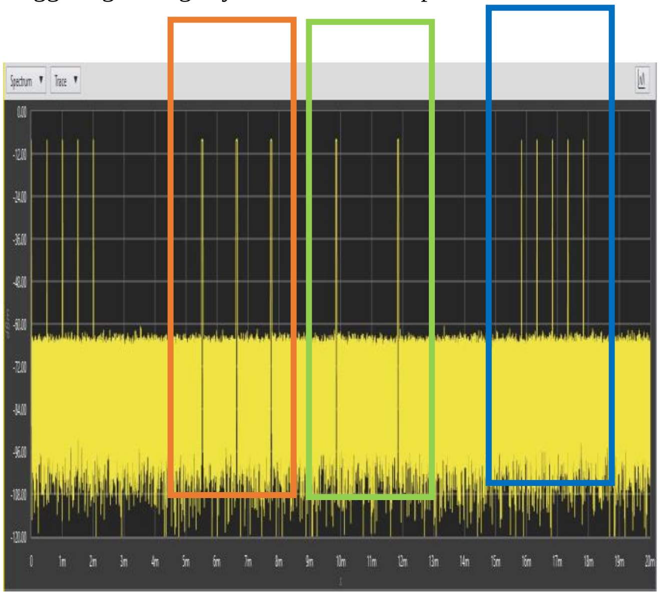

When you click on the script assistant, a Window will pop up, loaded with existent configuration. You will have the option to clear the current config, then add line by line a new pulse train configuration, remove the last line added, and save your configuration to a text file. Yu can equally load a predefined file on disk.


When you click on Add, an interactive Panel will open for you to configure the modulation parameters similar to the one in the main panel:



You can use the script to generate a custom train that can include different modulations and frequencies, i.e. pulse staggering and agility. Here is an example:



**Note: Frequency Agility is not supported in this example.**

4. IQ Waveform

This section displays the baseband generated signal. You can display the entire pulse train if you enable the **Display Pulse Train Button.** This option shows the entire count of pulses as configured. Care should be however taken as enabling this option all the time might overflow the memory as it concatenated all pulses for display. This option is automatically disabled for pulse count larger than 20 in a train. If you select the script option for generation, the graph will display one instance of each modulation configured concatenated together (i.e. display pulse count =1). To verify actual generation, RFmx Zero Span can be used.

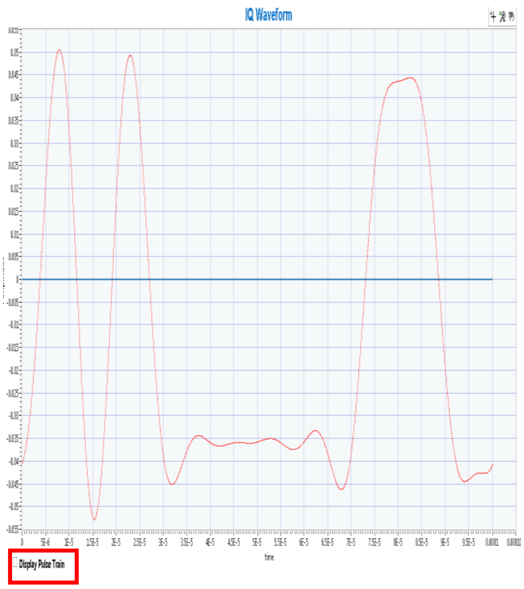



Figure 3 : Display Pulse Train Disabled

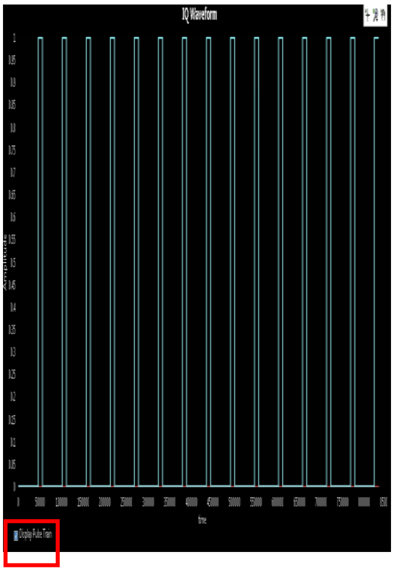



Figure 4: Display Pulse Train Enabled

Additional Options

Additional Buttons and Indicators reside in the UI:

Generation status: This indicator shows when the instrument is actually generating a signal/ It will be in OFF position is there is an error or the instrument is in configuration mode


Figure 5: Generating Signal


Figure 6: Error or in Configuration

- Update Config: You need to click this button every time you modify the UI configuration. When you click this button, the generation status turns off until the configuration is done and the instrument is generating again


Figure 7: Button to update Config

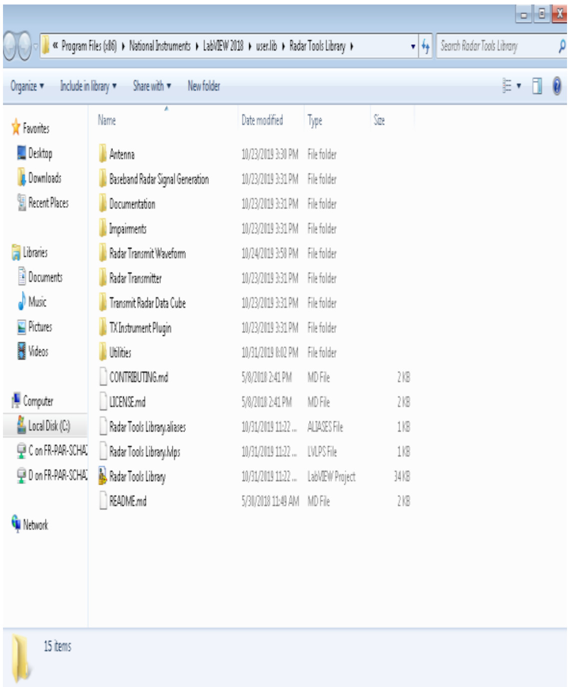
- Stop: This button will stop generation and the entire application. To launch the application again you must click on the run arrow to the top left of the toolbar


Figure 8: Stop Button

- Status Bar: This bar will display any error that occurs during execution. In case of error, the application stops automatically and the status bar shows the error sign with the error code
and a message explaining where the error came from. To get more info about the error, right click the message and click on **Explain Error.**

Figure 9: No Error

Figure 10: Error displaying message about IQ incompatibility



5. Access to Physical Ports and Digital Lines

You should note the following configurations when using the application:

- **Access to Trigger line:** The code exports a trigger based on a marker event for each pulse train generated (a pulse train is either the pulse count you configure interactively or if using the script, you will have a pulse train for each line in the table). The trigger exported can be used to drive the analyzer of an external DUT (PA for instance). You can access the trigger on
- **PXI-Trig0** line. To modify the line you can go to Configure VI of the RFSG Class
- **Access to RF Ports:** This application supports all lines of NI VST (564x, 584x and 583x). If you are using the 5830/1 then the IF port used to generate Data is port IF0. To modify the port, you can go to Initialize VI of the RFSG Class

Getting started:

The example is stored in following directory ***C:\Program Files (x86)\National Instruments\LabVIEW 201x\user.lib\Radar Tools Library*** for 32 bits or in ***C:\Program Files\National Instruments\LabVIEW 201x\user.lib\Radar Tools Library*** for 64 bits

To open the example, first double-click on the project file **Radar Tools Library** with type ***LabVIEW Project***

1- When the project opens, double click on the VI **Radar Signal Generation UI.vi** under the project tree. This will open the main UI. Choose the VI adapted to your screen resolution.

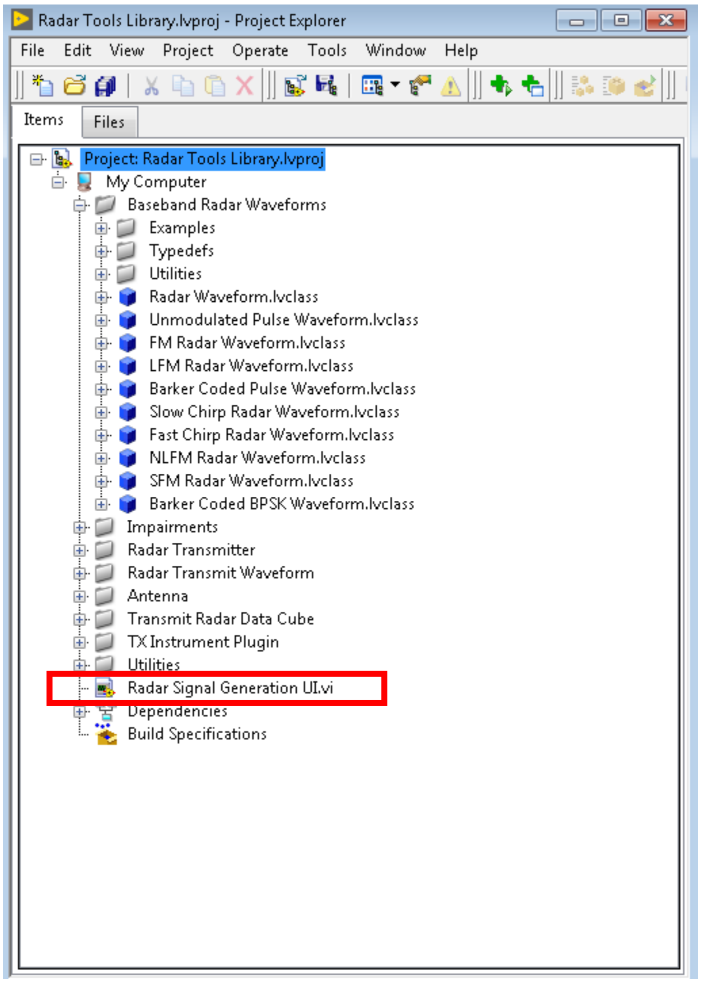



Figure 11: Project Tree

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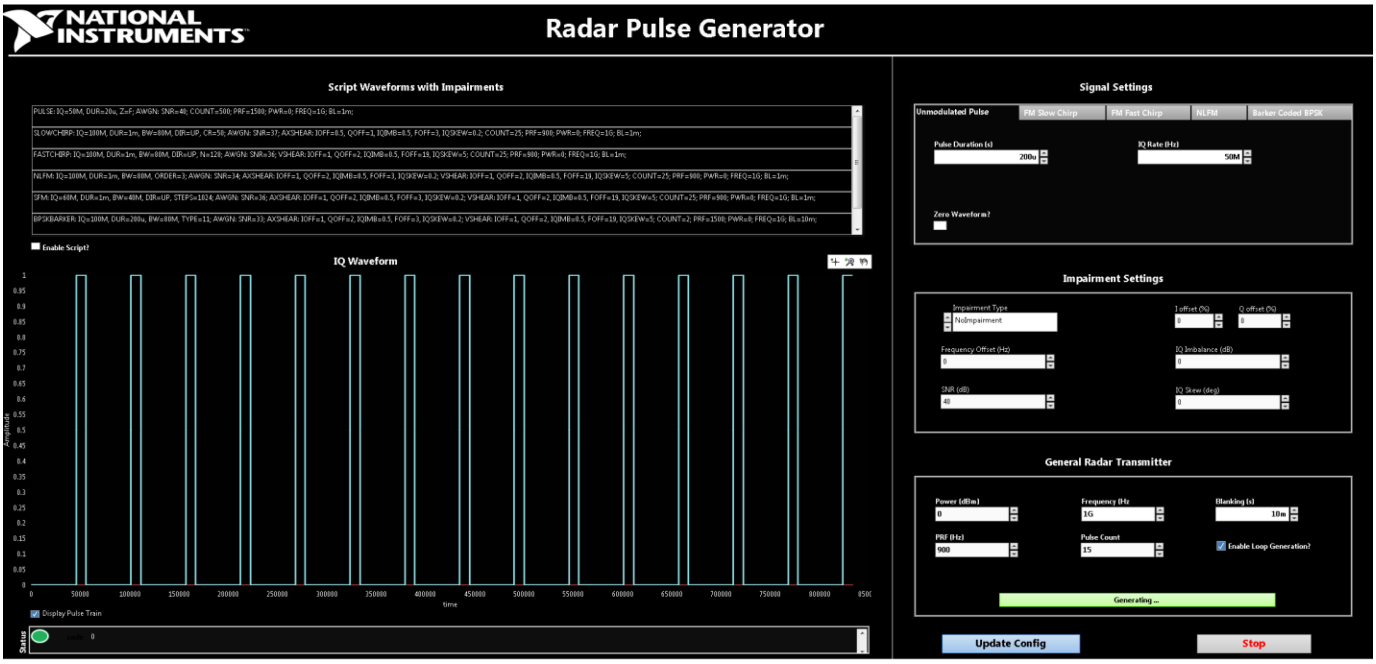
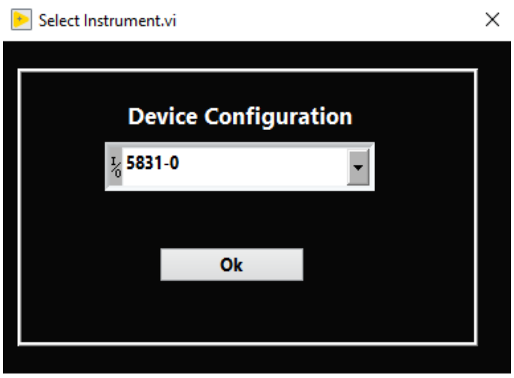



Figure 12: Main UI




2- Configure the different parameters as desired. Don't forget to enable script if you wish to run the preconfigured signal, disable the loop generation if you wish to generate a single pulse train, enable the pulse train display to view all the pulse count

3- Run the VI by clicking on the arrow to the top left side

4- Once the application starts, a pop-up window will appear to ask for the device configuration. From the pop up, use the dropdown menu to select which instrument you want to use for generation. In case you had multiple instruments, you can consider renaming the devices in NI Max as described later in this document

To reconfigure, change any UI parameter, then click on Update Config 6- Click on Stop to stop execution

7- To debug the pulse generation, you can loop back into the instrument or use any VSA to receive the signal and view the pulse. You can use RSFA Soft Front Panel or RFmx SpecAn. You will need to configure the SFP in Zero Span and you can modify the sweep time, the RBW, VBW and carrier frequency to match your Tx Configuration AND TRIGGER;

***Trigger :***

The Tx generates a trigger for each marker on the PXI chassis backplane using PXI Trigger Line

0. If you wish you to use this Digital edge as source of Trigger, you need to select **PXI_Trig0** as

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input. Alternatively, you can trigger on IQ Power Edge where you need to configure the trigger level

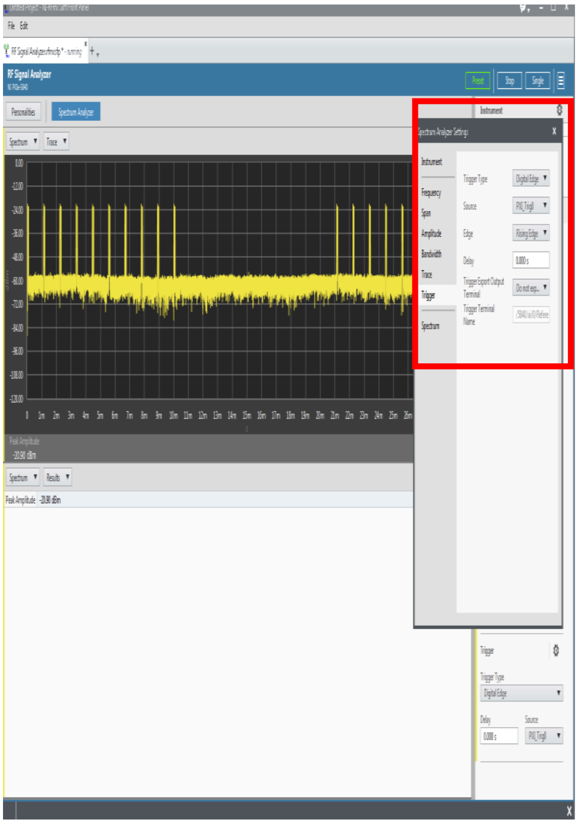


Figure 13: Configure Zero Span in RFmx SpecAn with Digital edge Trigger

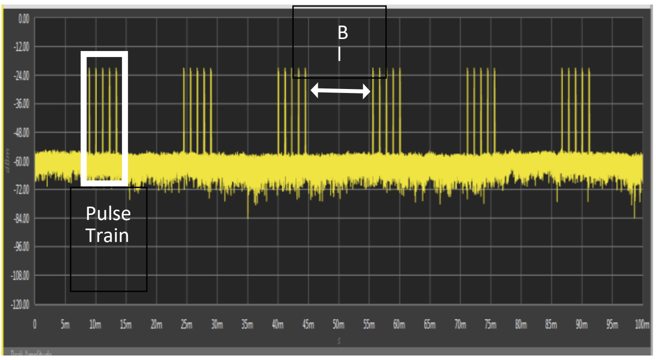



Figure 14: Pulse Example

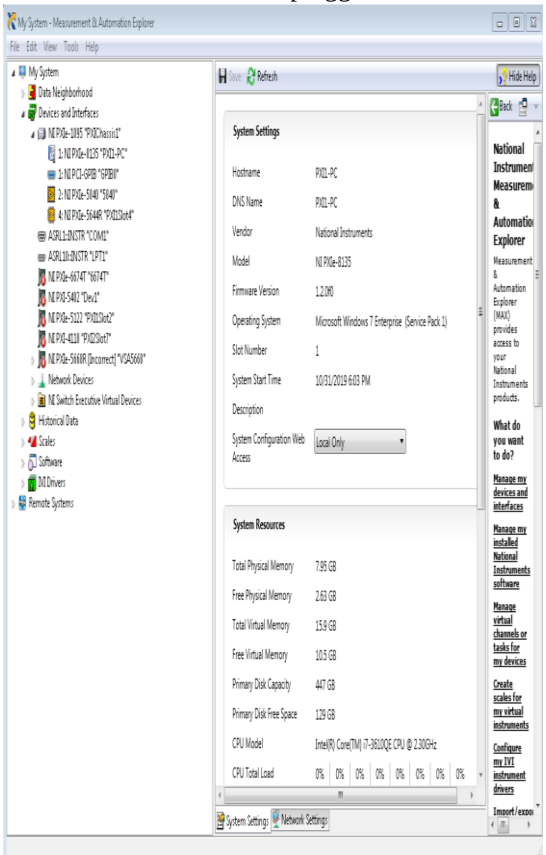
Configure Device in NI-MAX

NI-MAX (NI Measurement and Automation Explorer) is a standalone software that installs with the instrument driver, it is used to monitor connectivity to Hardware, self-test and self-calibrate instruments. To configure your instrument:

1- Launch NI Max from Windows home by typing NI MAX

**2-** Go to **My system>> Devices and Interfaces**

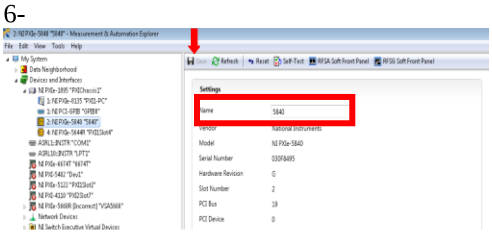
3- Expand the PXI Chassis Entry. You will see the list of devices plugged into the chassis



4- Select the VST of interest. This will show the instrument related settings in the window to the right

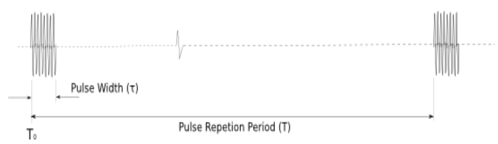
5- Under Settings, write the Alias of choice in the Name entry then click on Save in the top right toolbar. If the name is unchanged, the save button is disabled. The Alias you configured will appear in the instrument drop down during execution

6-



Support &Feedback

For future support related to this application or for bugs reports of feature improvement, please post a comment on the community



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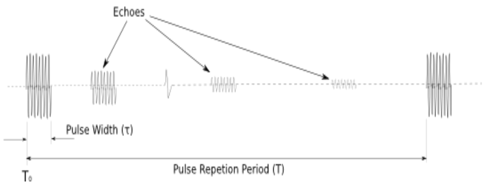
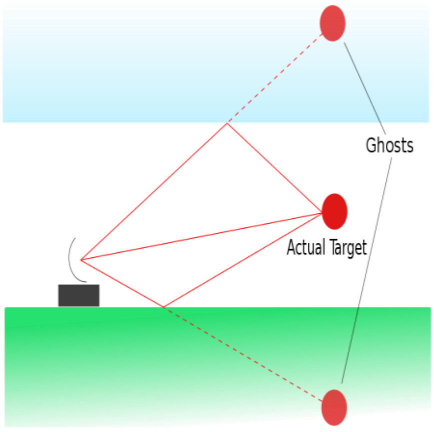
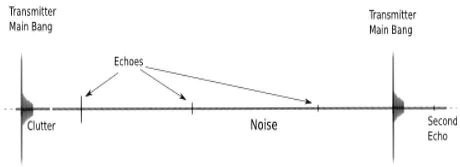
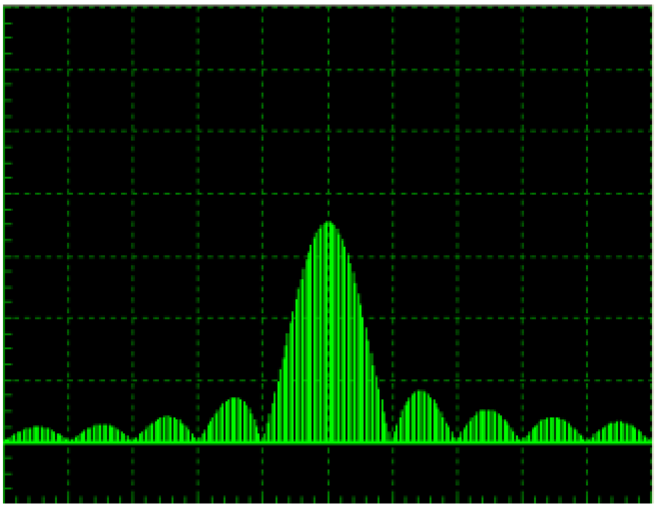


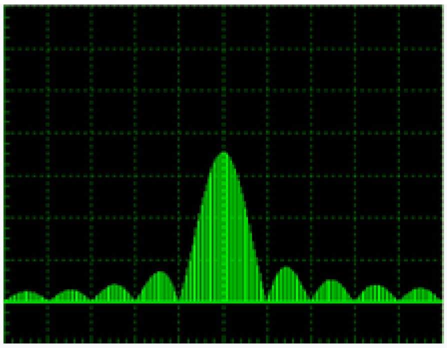



## Typical system parameters

Taking all of the above characteristics into account means that certain constraints are placed on the radar designer. For example, a system with a 3 GHz carrier frequency and a pulse width of 1 µs will have a carrier period of approximately 333 ps. Each transmitted pulse will contain about 3000 carrier cycles and the velocity and range ambiguity values for such a system would be:

## The radar signal in the frequency domain[edit]

Pure CW radars appear as a single line on a Spectrum analyser display and when modulated with other sinusoidal signals, the spectrum differs little from that obtained with standard analogue modulation schemes used in communications systems, such as Frequency Modulation and consist of the carrier plus a relatively small number of sidebands. When the radar signal is modulated with a pulse train as shown above, the spectrum becomes much more complicated and far more difficult to visualise.



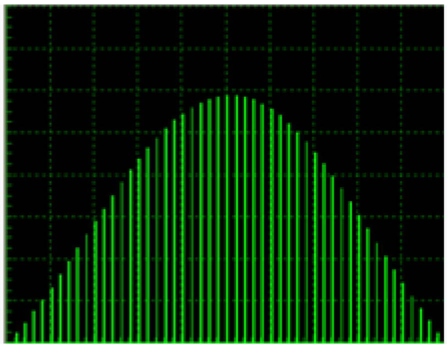
Basic radar transmission frequency spectrum

Basic Fourier analysis shows that any repetitive complex signal consists of a number of harmonically related sine waves. The radar pulse train is a form of square wave, the pure form of which consists of the fundamental plus all of the odd harmonics. The exact composition of the pulse train will depend on the pulse width and PRF, but mathematical analysis can be used to calculate all of the frequencies in the spectrum. When the pulse train is used to modulate a radar carrier, the typical spectrum shown on the left will be obtained.

Examination of this spectral response shows that it contains two basic structures. The coarse structure; (the peaks or 'lobes' in the diagram on the left) and the Fine Structure which contains the individual frequency components as shown below. The envelope of the lobes in

the coarse structure is given by: .

Note that the pulse width ( ) determines the lobe spacing. Smaller pulse widths result in wider lobes and therefore greater bandwidth.



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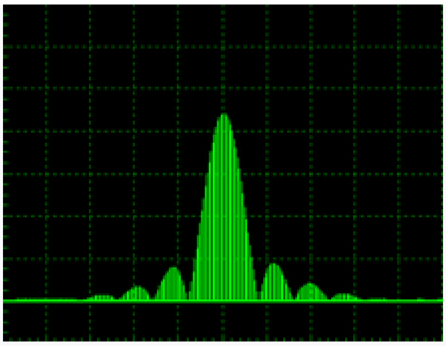
Radar transmission frequency fine spectrum

Examination of the spectral response in finer detail, as shown on the right, shows that the Fine Structure contains individual lines or spot frequencies. The formula for the

fine structure is given by and since the period of the PRF (T) appears at the bottom of the fine spectrum equation, there will be fewer lines if higher PRFs are used. These facts affect the decisions made by radar designers when considering the trade-offs that need to be made when trying to overcome the ambiguities that affect radar signals.

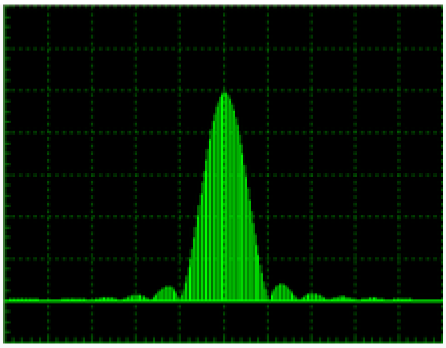
Pulse profiling**[edit]**

If the rise and fall times of the modulation pulses are zero, (e.g. the pulse edges are infinitely sharp), then the sidebands will be as shown in the spectral diagrams above. The bandwidth consumed by this transmission can be huge and the total power transmitted is distributed over many hundreds of spectral lines. This is a potential source of interference with any other device and frequency-dependent imperfections in the transmit chain mean that some of this power never arrives at the antenna. In reality of course, it is impossible to achieve such sharp edges, so in practical systems the sidebands contain far fewer lines than a perfect system. If the bandwidth can be limited to include relatively few sidebands, by rolling off the pulse edges intentionally, an efficient system can be realised with the minimum of potential for interference with nearby equipment. However, the trade-off of this is that slow edges make range resolution poor. Early radars limited the bandwidth through filtration in the transmit chain, e.g. the waveguide, scanner etc., but performance could be sporadic with unwanted signals breaking through at remote frequencies and the edges of the recovered pulse being indeterminate. Further examination of the basic Radar Spectrum shown above shows that the information in the various lobes of the Coarse Spectrum is identical to that contained in the main lobe, so limiting the transmit and receive bandwidth to that extent provides significant benefits in terms of efficiency and noise reduction.



Radar transmission frequency spectrum of a trapezoid pulse profile

Recent advances in signal processing techniques have made the use of pulse profiling or shaping more common. By shaping the pulse envelope before it is applied to the transmitting device, say to a cosine law or a trapezoid, the bandwidth can be limited at source, with less reliance on filtering. When this technique is combined with pulse compression, then a good compromise between efficiency, performance and range resolution can be realised. The diagram on the left shows the effect on the spectrum if a trapezoid pulse profile is adopted. It can be seen that the energy in the sidebands is significantly reduced compared to the main lobe and the amplitude of the main lobe is increased.

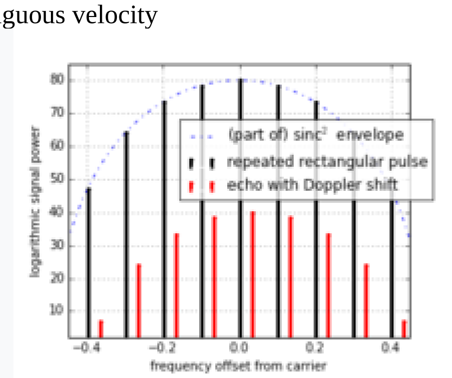


Radar transmission frequency spectrum of a cosine pulse profile

Similarly, the use of a cosine pulse profile has an even more marked effect, with the amplitude of the sidelobes practically becoming negligible. The main lobe is again increased in amplitude and the sidelobes correspondingly reduced, giving a significant improvement in performance.

There are many other profiles that can be adopted to optimise the performance of the system, but cosine and trapezoid profiles generally provide a good compromise between efficiency and resolution and so tend to be used most frequently.

Unambiguous velocity




Doppler spectrum. Deliberately no units given (but could be dBu and MHz for example).

This is an issue only with a particular type of system; the pulse-Doppler radar, which uses the Doppler effect to resolve velocity from the apparent change in frequency caused by targets that have net radial velocities compared to the radar device. Examination of the spectrum generated by a pulsed transmitter, shown above, reveals that each of the sidebands, (both coarse and fine), will be subject to the

Doppler effect, another good reason to limit bandwidth and spectral complexity by pulse profiling.

Consider the positive shift caused by the closing target in the diagram which has been highly simplified for clarity. It can be seen that as the relative velocity increases, a point will be reached where the spectral lines that constitute the echoes are hidden or aliased by the next sideband of the modulated carrier. Transmission of multiple pulse-packets with different PRF-values, e.g. staggered PRFs, will resolve this ambiguity, since each new PRF value will result in a new sideband position, revealing the velocity to the receiver. The maximum unambiguous target velocity is given by:

| PRF | Velocity Ambiguity | Range Ambiguity |
|---|---|---|
| Low (2 kHz) | 50 m/s | 75 km |
| Medium (12 kHz) | 300 m/s | 12.5 km |
| High (200 kHz) | 5000 m/s | 750 m |
| 150MHz GPR | 1000 m/s | 75 m |
| 1000MHz GPR | 1000 m/s | 100 m |

The overrated value of the reliability of manufacturing system will not only deteriorate the produced product reliability and may also lead to a wrong maintenance strategy or miss the best opportunity for system maintenance. To conclude, it is critically essential to consider the coeffects between process quality and system components reliability when modeling and assessing the reliability of manufacturing system. For future research, the following topics should be further expounded.

(1) The improvement of the reliability optimization model based on the quality loss for different type of manufacturing system is needed. The coefficients of the optimization model are different for different manufacturing system; therefore, how to estimate accurately the coefficients from the big data from manufacturing system design, operation, and maintenance is planned.

(2) The quantitative mathematical relationship of the manufacturing system reliability, manufacturing process quality, and the produced product reliability should be established successively. Specifically, the mathematical impact of the manufacturing system reliability on the produced product reliability should be constructed clearly, which should provide a solid foundation for the integrated reliability and maintenance optimization framework of the various types of manufacturing system.

(3) In the last perspective research, we consider the aspect of reliability modeling and assessment in the design and setup of manufacturing system. The reliability level is determined in the design process of the manufacturing system, in order to satisfy the everincreasing stringent quality and reliability requirements, the reliability design should be integrated with the functional design of manufacturing system, and new design theory like Axiomatic Design should be adopted into reliability design of manufacturing system.

## CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the publication of this paper.

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## REFERENCES :

[1] Y. He, W. Linbo, Z. He, and M. Xie, "A fuzzy TOPSIS and rough set based approach for mechanism analysis of product infant failure," Engineering Applications of Artificial Intelligence, 2015.

[2] M. Colledani, T. Tolio, A. Fischer et al., "Design and management of manufacturing systems for production quality," CIRP Annals: Manufacturing Technology, vol. 63, no. 2, pp. 773–796, 2014.

[3] P. Murthy, "New research in reliability, warranty and maintenance," in Proceedings of the 4th Asia-Pacific International Symposium on Advanced Reliability and Maintenance Modeling (APARM '10), pp. 504–515, McGraw-Hill International Enterprises, Wellington, New Zealand, December 2010.

[4] R. Jiang and D. N. P. Murthy, "Impact of quality variations on product reliability," Reliability Engineering & System Safety, vol. 94, no. 2, pp. 490–496, 2009.

[5] J. Li and N. Huang, "Quality evaluation in flexible manufacturing systems: a Markovian approach," Mathematical Problems in Engineering, vol. 2007, Article ID 57128, 24 pages, 2007.

[6] J. Li and J. Lei, "Integration of manufacturing system design and quality management," IIE Transactions, vol. 45, no. 6, pp. 555– 556, 2013.

[7] Z. Hajej, N. Rezg, and A. Gharbi, "A decision optimization model for leased manufacturing equipment with warranty under forecasting production/maintenance problem," Mathematical Problems in Engineering, vol. 2015, Article ID 274530, 14 pages, 2015.

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[8] Z. Hajej, S. Turki, and N. Rezg, "Modelling and analysis for sequentially optimising production,maintenance and delivery activities taking into account product returns," International Journal of Production Research, vol. 53, no. 15, pp. 4694–4719, 2015.

[9] L. Mifdal, Z. Hajej, and S. Dellagi, "Joint optimization approach of maintenance and production planning for a multipleproduct manufacturing system," Mathematical Problems in Engineering, vol. 2015, Article ID 769723, 17 pages, 2015.

[10] J. Shi, Stream of Variation Modeling and Analysis for Multistage Manufacturing Processes, CRC Press, Taylor & Francis, 2007