Multi-channel Splicing Technology for Signal Bandwidth Expansion

Bangqian Wan[1, a], Zhiyong Yu[1], and Jian Yang[2]

[1]Xi'an Research Institute of Hi-Tech Hongqing Town, Xi'an, 710025, P.R. China

[2]National Key Laboratory of Radar Signal Processing, Xidian University Xi'an, 710071, P.R. China

[a]760853241@qq.com

Keywords: broadband signal, multi-splicing, computer simulation.

Abstract. With the demand for wide bandwidth signals intensified, broadband signal generation technology based on multi-splicing is gradually emerging. Currently, signal splicing technology is mainly deployed for the chirp signal. To expand the signal range of styles can be spliced, get more types of broadband signals, in this paper, the typical radar signal style in-depth analysis. The characteristics of the splicing of the signal are proposed and verified by computer simulation. It provides an important reference for the engineering realization of splicing different types of signals.

1. Introduction CCA

Modern radar not only to complete the extraction of the target position, speed and other information, but also to image the target analysis and identification. So the design of radar signal source capable of generating a large bandwidth for broadband radar equipment performance testing and evaluation is very important. At present, through the digital way to obtain pulse compression signal has become a modern radar commonly used waveform synthesis method. In addition, the theoretical model of ultra-wideband millimeter-wave signal based on dual-drive Mach-Zehnder modulator was established at the Institute of Optoelectronics, Shanghai University of Technology. And the use of theoretical model for the actual operation of the simulation produced a bandwidth of 5.8GHz ultra-wideband millimeter wave signal[1];Electronic Information Engineering, Tianjin University and Shanxi Datong University School of Physics and Electronic Science Guo Jingzhong, Yu Jinlong, who proposed a three-wavelength injection based on Fabry - Perot laser diode (FP-LD) generating ultra-wideband signals Program. The full width of the half-width of the pulse signal is 83.3ps and the bandwidth of 10dB is about 4.6GHz [2].However, to produce broadband pulses must meet the requirements of narrow pulse width, power limit, stable output, etc., there are different ways to generate and receive these signals and to encode the transmitted information, either individually or in groups, and according to amplitude, Phase and pulse position to encode the information. For low amplitude narrow pulse circuit, there are many options available, such as tunnel diodes, avalanche transistor, step recovery diode and capacitance differential [3]. Due to the limitation of the pulse generator, the width and amplitude of the pulse are often mutually constrained, and the narrower the pulse, the higher the performance requirements of the components, the technical difficulty and the corresponding increase in the cost. Therefore, taking into account the signal quality and cost of multi-channel splicing technology has important research value, which first need to address is the signal can be spliced, this article will discuss this.

2. Signal Can be Spliced Analysis to Nature

Different systems of radar, due to the different functions to be achieved, the radar signal style is correspondingly more. However, whether all the radar signals can be spliced by the way to expand the signal bandwidth remains to be demonstrated. Therefore, it is first necessary to explore the nature of the mosaic of multiple signals. The use of multi-channel splicing technology to synthesize broadband signals, the purpose is to reduce the hardware clock requirements to obtain large instantaneous bandwidth signal. The following will be from the signal of the different characteristics of the relationship between the characteristics of the signal can be spliced to analyze the nature.

2.1 The Frequency Relationship between the Multi-Channel Signal

To linear frequency modulation signal (LFM), for example, its time-frequency relationship [4] as shown in Figure 1.1.

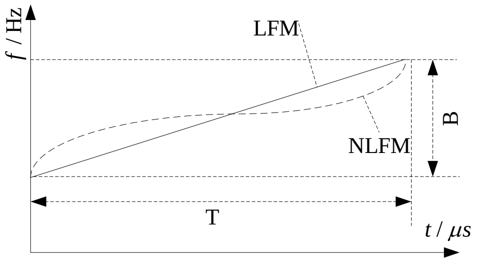

Figure 1.1 Time-frequency distribution of linear and non-linear FM signals

The linear frequency modulation signal shown in Fig. 1.1 is divided into four sections in time, and the four signals are aligned from the phase before splicing, so that the signals can be connected from the time domain to the four signals. The spliced signal will be scaled up to four times the bandwidth of the single signal before splicing. The principle of multiple signal splicing is shown in Figure 1.2.

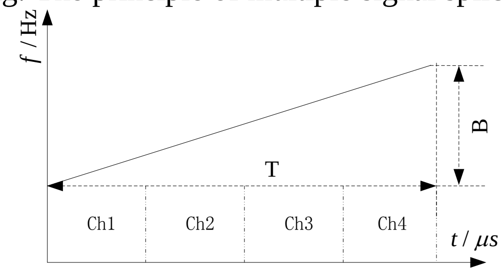

Figure 1.2 Schematic diagram of multiple signal splicing

The non-linear frequency modulation signal (NLFM) is similar to the chirp signal and can be analyzed in a similar way. As shown in Figure 1.1, the nonlinear time-frequency signal is divided into four segments in time-width and the four-channel signal signal is kept in phase alignment before splicing.

In addition, for the homogeneous pitch coherent signal in the burst signal, the mathematical envelope expression is,

$$u(t)=\frac{1}{\sqrt{N}}\sum_{n=0}^{N-1}u_1(t-nT_r) \tag{1}$$

From the formula, we can see that the signal does not exist in the pulse modulation, but in the time domain to increase the cycle of the pulse train, by adding the pulse signal in the time domain, and do Fourier transform, and finally the resulting signal is non-monotonic in the frequency domain and cannot be extended. Obviously, through the multi-splicing synthesis of broadband signals first need to be synthesized between the various signals with frequency increments, that requires $\Delta f \geq 0$ among the multi-chnanel signals. For non-inverting signals, it is not possible to broaden the signal bandwidth directly by means of multiple splicing techniques because even if the signal is multiplexed in the time domain, the resulting signal is only expanded in the time domain and the resulting The frequency band of the signal is not widened compared to the single signal. Therefore, through the multi-channel splicing to expand the signal bandwidth, must meet the frequency of the signal between the incremental.

2.2 Time Domain Relationship between Each Channel Signal

In Section 1.1, we analyze the continuous frequency progressive signal (such as LFM) in the time domain, and conclude that the time-domain discrete signal can also be spliced. Taking the frequency stepping signal in the frequency encoded signal as an example, the waveform diagram is shown in the figure,

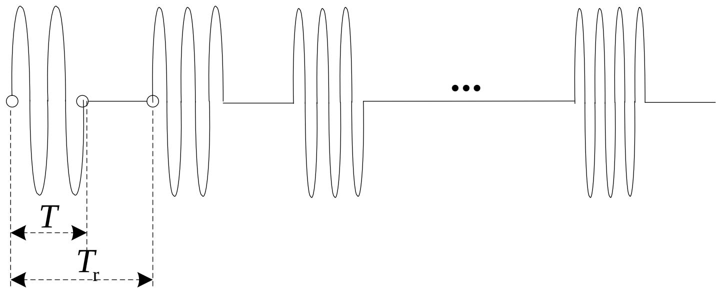

Figure 1.3 Schematic diagram of stepped frequency waveforms

Forward stepped frequency signal carrier frequency variation [4] as shown in Figure 1.4,

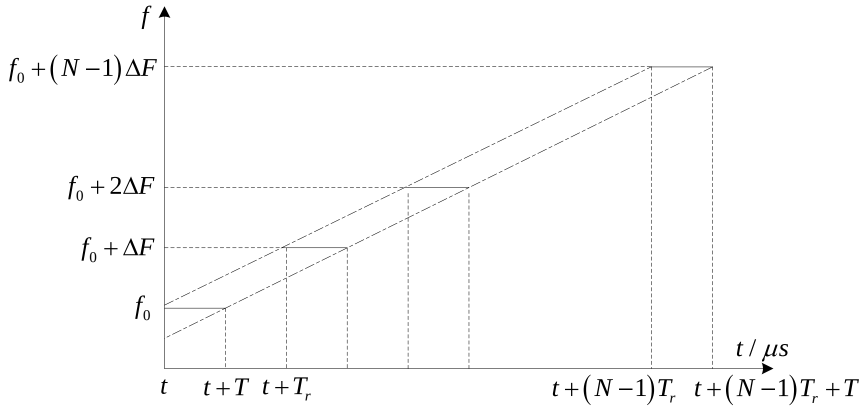

Figure 1.4 Carrier frequency variation of forward frequency stepping signal

Its time-frequency relationship with the LFM signal is very similar, can be seen as a ladder of the LFM signal. Each pulse can be narrow, through the synthesis of the pulse, can be equivalent to improve the pulse signal bandwidth, the greater the frequency step step, the more the number of pulses, the higher the distance resolution. For this signal, N(assuming N is an integer multiple of 4) pulses can be divided into four signals also, and in the time domain splicing synthesis, the final signal in the frequency domain is discrete monotonically increasing, theoretically in line with the bandwidth Expansion requirements. Thus, the mosaic of the multiplexed signal is independent of the time domain continuity of the signal. However, it is worth noting that at this time we spliced the signal did not extend the instantaneous bandwidth of the signal, but according to the frequency of the bandwidth of the bandwidth expression $\mathrm{B}=\mathrm{N}\Delta F$, by increasing the pulse sequence number of step pulse N, thus expanding the signal the working bandwidth. Of course, if it is to splice the signal of the instantaneous bandwidth, it is required to be spliced signal in the time domain has continuity, which is consistent with the definition of radar signal instantaneous bandwidth.

2.3 In the Previous Two Sections, We Mainly Analyze the Waveform Rules.

The following for the waveform irregular signal to discuss whether it can be stitching. To time-frequency encoded signal, for example, its plural form can be expressed as a unified

$$s(t)=\sum_{n=0}^{N-1}u_1(t-nT_r)\exp\left(j2\pi\Delta f_n t+j2\pi f_0 t\right) \tag{2}$$

When $\Delta f_n = r\Delta F, r\in[a,b], a,b$, the above equation is random frequency hopping signal. From (2), we can see that its frequency size does not change with the law of time, even if the multi-channel random frequency hopping signal directly spliced, then the spliced signal can achieve the requirements of the extended signal bandwidth is also random, contrary to the intention of the signal multi-channel stitching.

In summary, the basic requirement for spliced synthesis of multiple signals is that the signals should be incremented in frequency and that the single signal remains regular on the waveform. For single-frequency, narrow-band signal can be considered through the up-conversion, frequency [5] and other ways to deal with splicing conditions and then multi-splicing synthesis.

3. Experimental simulation verification

First, for the frequency increasing signal of the splicing simulation. Figure 2.1 is a four-channel LFM signal. Their frequency range is 9MHz-11MHz, 11MHz-13MHz, 13MHz-15MHz, 15MHz-17MHz, the signal sampling frequency of 40MHz, and FM bandwidth of 2MHz.

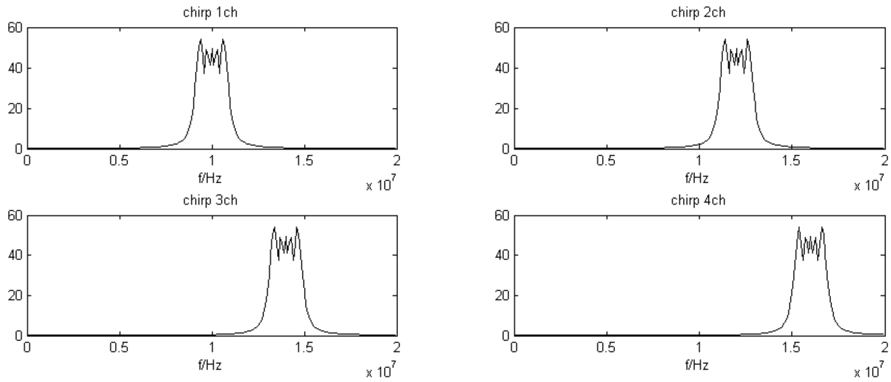

Figure 2.1 Four channels LFM signal spectrum

Figure 2.2 is a LFM signal spliced from four channels LFM signal by matlab simulation. It is the use of four signals in the time domain to do phase alignment processing, and then stitching, and finally through the Fourier transform of the synthesized signal, its frequency range is 9MHz-17MHz, bandwidth spread to single-channel signal 4 times.

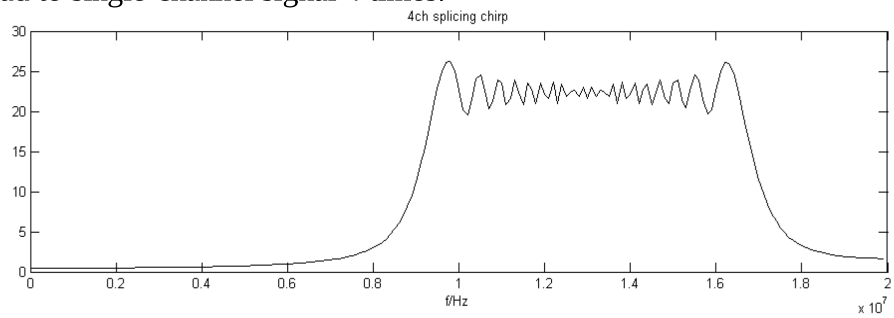

Figure 2.2 Four-channel splicing LFM signal spectrum

The results show that the multi-channel chirp signal, which is theoretically incremental in the frequency domain, can be combined into a signal by splicing, and the bandwidth is expanded.

Second, for the time domain discrete signal splicing simulation. In front of the time has been continuous single signal (linear FM signal) made splicing simulation, the following time-domain discrete signal simulation. Take the frequency stepping signal as an example, the frequency stepping signal is a typical frequency encoded signal, the forward frequency step signal can be expressed as:

$$s(t)=\sum_{n=0}^{N-1}u_1(t-nT_r)\exp\left(j2\pi f_0 t\pm j2\pi n\Delta Ft\right) \quad (3)$$

Similar to the chirp signal multiplexing splicing, can make $N1=N2=N3=N4=4$ $T_r=0.8\mu s$ f_{01} =4MHz f_{02} =8MHz f_{03} =12MHz f_{04} =16MHz Δ F=1MHz four stepped frequency signal shown in Figure 2.3.

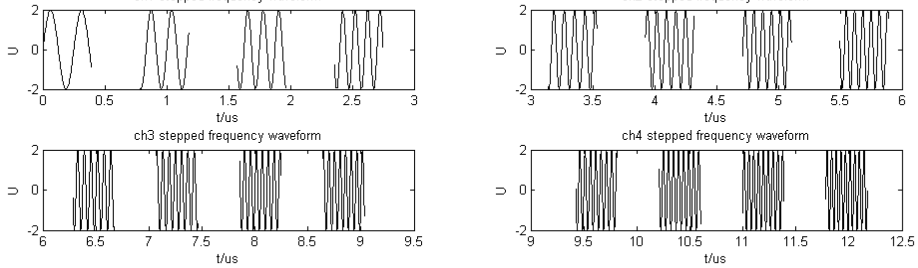

Figure 2.3 Four-channel stepped frequency signal waveform chart

Then, the four-channel signal in order of time domain, before and after the connection, and through the power accumulator add, get spliced signal shown in Figure 2.4, splicing the signal bandwidth from a single 4MHz to 16MHz. The results show that theoretically, for discrete multi-channel stepping signals and continuous signals can be combined into a signal by splicing, and with respect to the bandwidth of a single signal is widened.

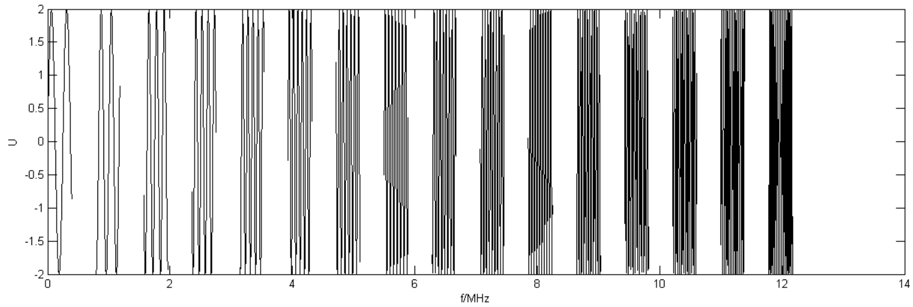

Figure 2.4 Four-channel splice stepped frequency signal waveform chart

Third, for the waveform irregular signal splicing simulation. In front of the time domain waveform has been the regular signal (LFM signal and stepped frequency signal) to do the simulation, the following will be time domain waveform irregular signal simulation. Figure 2.5 shows the time domain waveform of the quadruple frequency conversion signal. From this graph, we can see that the time domain sparsity of the signal is randomly changed. That is, the signal does not exist in the frequency domain.

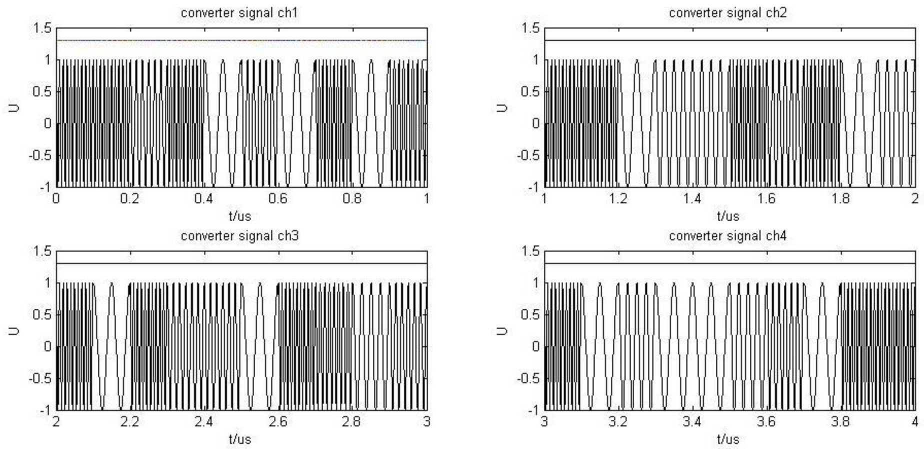

Figure 2.5 Four-channel conversion signal waveform

Through the splicing of the signal shown in Figure 2.6, from the figure we can see that the spliced signal in the time domain still does not have the waveform regularity, and the signal sparseness change is not regular, splicing the signal in the frequency domain without bandwidth expansion.

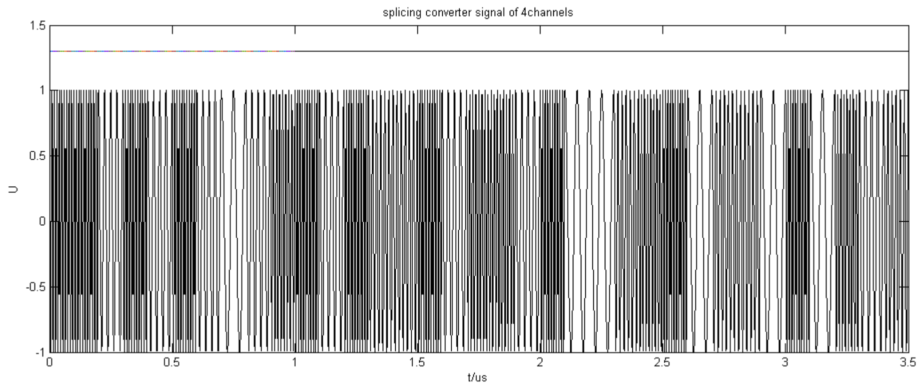

Figure 2.6 Waveform of the four-channel splicing signal

4. Conclusion

In this paper, several typical radar signals are analyzed from the splicing of the signal, and the frequency of the signal is increased from the frequency increment, the time domain continuity and the waveform regularity of the single signal. Essence, the conclusion that the frequency increment and the waveform regularity are the essential attributes of signal splicing. Finally, the results are verified by computer simulation, which provides theoretical support for the engineering realization of broadband signal splicing.

Acknowledgements

This work is partly supported by the National Natural Science Foundation of China under grant 61501471.

References

[1]. Wang Dong, Dai Bo, etc.Based on the Mach-Zehnder modulator to produce 24GHz band ultra-wideband signal millimeter wave [J]. Acta Photonica Sinica2015, 9.
[2]. Guo Jingzhong, Yu Jinlong et al. Ultra-wideband signal generation technology based on injection locking Fabry-Perot laser diode [J]. Chinese Journal of Laser Science.
[3]. Fei Yuanchun, Su Guangchuan, etc. Broadband radar signal generation technology [M]. Defense Industry Press .2005.
[4]. Wei Yinsheng. Radar signal theory and application (foundation) [M]. Harbin Institute of Technology Press .2011.
[5]. Yu Naiyi .10MHz to 10GHz signal source design and implementation [D]. University of Electronic Science and Technology .2013.