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A Clutter Reduction Algorithm in Non-Coherent LFM CW Radars

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Abstract

The algorithm of clutter reduction in LFM CW radars is presented. Similarities in sequential measurements are formalized via the introduced identification function. The ensemble averaging allows significantly to simplify the moving target identification.

Keywords: algorithm, clutter reduction, FMCW radar, moving target indication.

1. Introduction

Portable CW radars have recently found wide application in military and civil areas taking into account a number of requirements, such as: small dimensions, competitive price, and so on. Among the main areas of application for the mentioned radars are surveillance security systems, vehicle collision avoidance systems, etc. [1], [2]. The recently developed applications imposed specific requirements on radars parameters; hence, the parameters of such systems should be improved. The mentioned systems are considered as “intellectual” radio devices and need a serious software support for effective operation. For this purpose, the development of efficient algorithms is vital. As it is known, one of the most important parameters of radar systems is its dynamic range. The total capability of the system can be improved by dynamic range boosting, although it is not always sufficient. Sometimes the indirect improvement of system parameters can be more efficient. These include: the suppression of the reflected signal from the local objects (clutter), which will have the same result as the dynamic range boosting. This problem, in traditional coherent-pulse radar systems, is solved by periodical comparison of the received signals of more than two neighboring pulses, and detection of their spectral differences [6]. In CW radar the situation substantially differs, since in this case the spectra are not fully identical and there is only likeness between them. Thus, the problem is summarized in detecting similarities of signal spectra received from the neighboring sequential periods.

2. System and Measurements

One of the most effective ways of distance measurement with CW radars is using of a linear frequency modulation (LFM). The system transmits LFM signal with the periodically rising and falling frequency slopes. Such measurements during the slopes will allow us to identify the distance and the radial speed of the target. The signal reflected from the target contains a frequency shift, simultaneously due to the signal delay and Doppler Effect. The received signal is down converting and the result is the beating signal shown in Fig. 1.

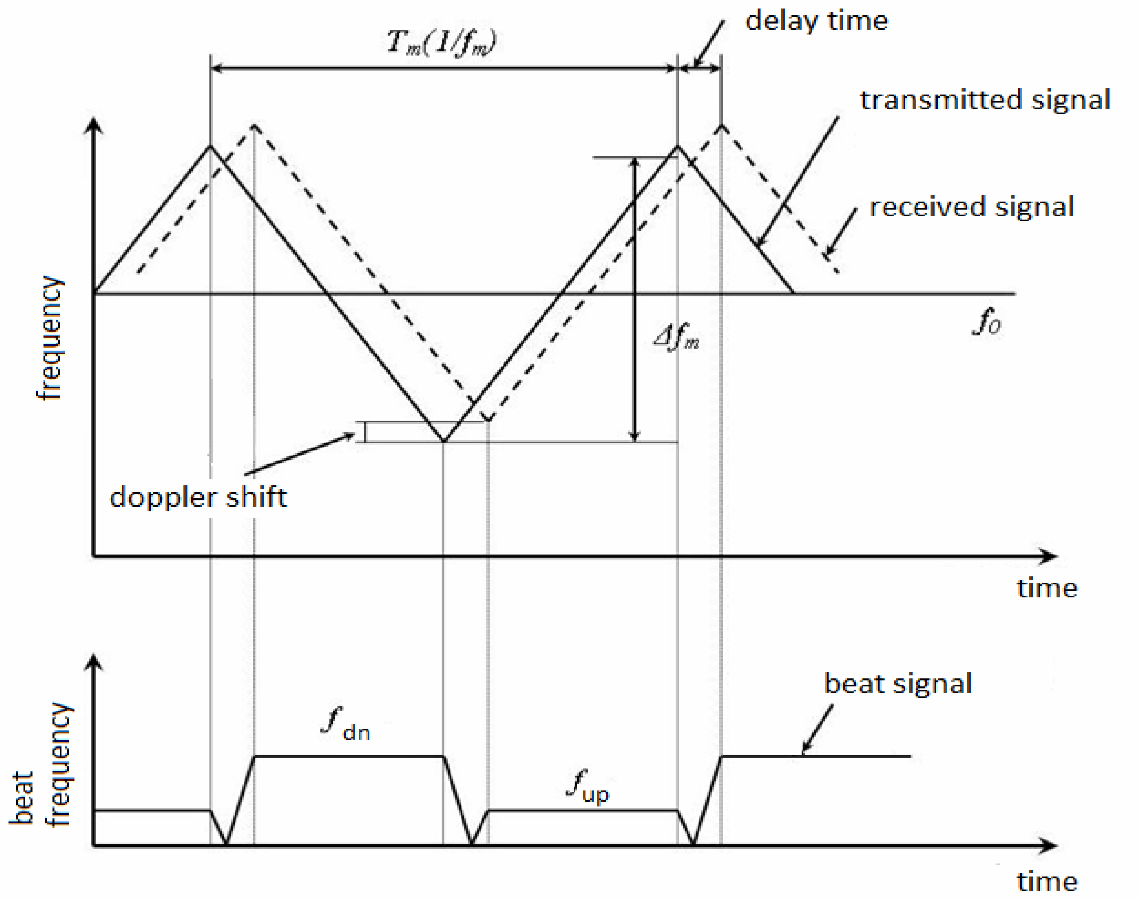


Fig. 1. FMCW triangular waveform and beating signal

The achieved signal is the sequence of signals with f_{up} and f_{down} frequencies corresponding to the LFM up- and down-periods. Depending on the target movement direction and the period of the transmitted signal, the possible values of the resulting frequency are:

$$f_1 = |f_{delay} + f_{doppler}|. \tag{1}$$

$$f_2 = |f_{delay} - f_{doppler}|. \tag{2}$$

Thus, it is obvious, that the detected frequencies of the signal reflected from local objects will be the same for rising and falling slopes. Meanwhile for the case of the moving object they will differ by the value of twice of the Doppler frequency [3], [5]. We have carried out a huge amount of spectral measurements including clutter, human and vehicle targets.

The spectra of down converted signals for up- and down-periods are shown in Fig. 2 (clutter), meanwhile the same for the moving targets is shown in Fig. 3. Although, the spectra of the signal reflected from the clutter are not strictly identical, but there is a qualitative resemblance between them.

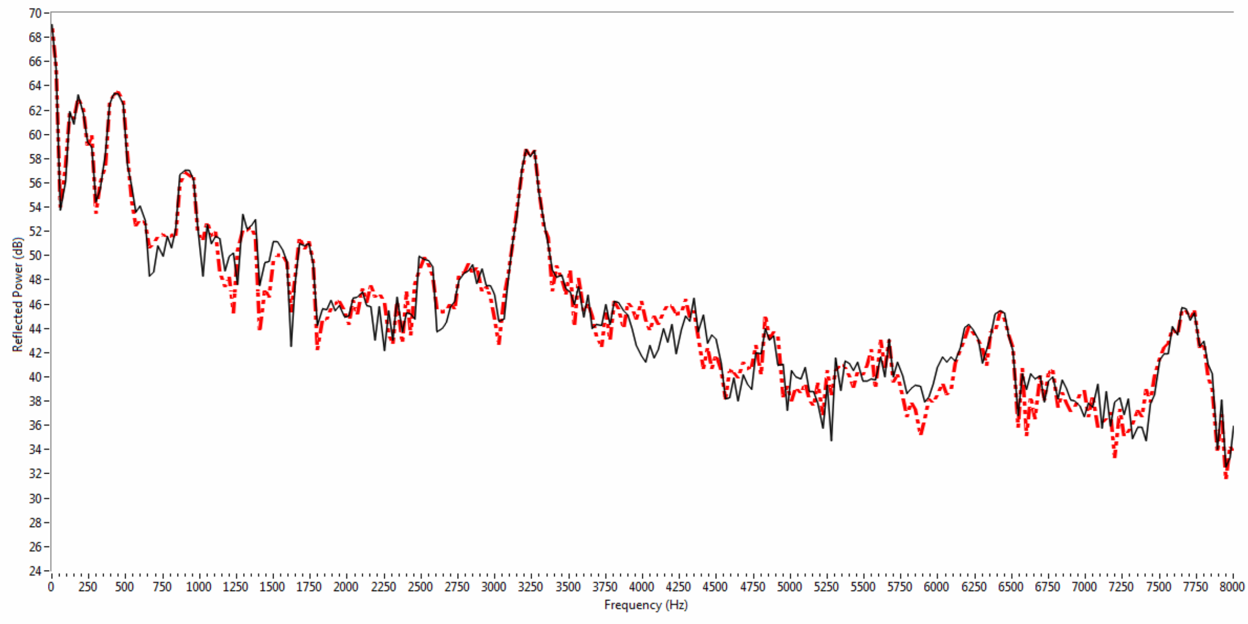


Fig.2. Spectra of clutter (solid – up- spectrum, dashed – down- spectrum)

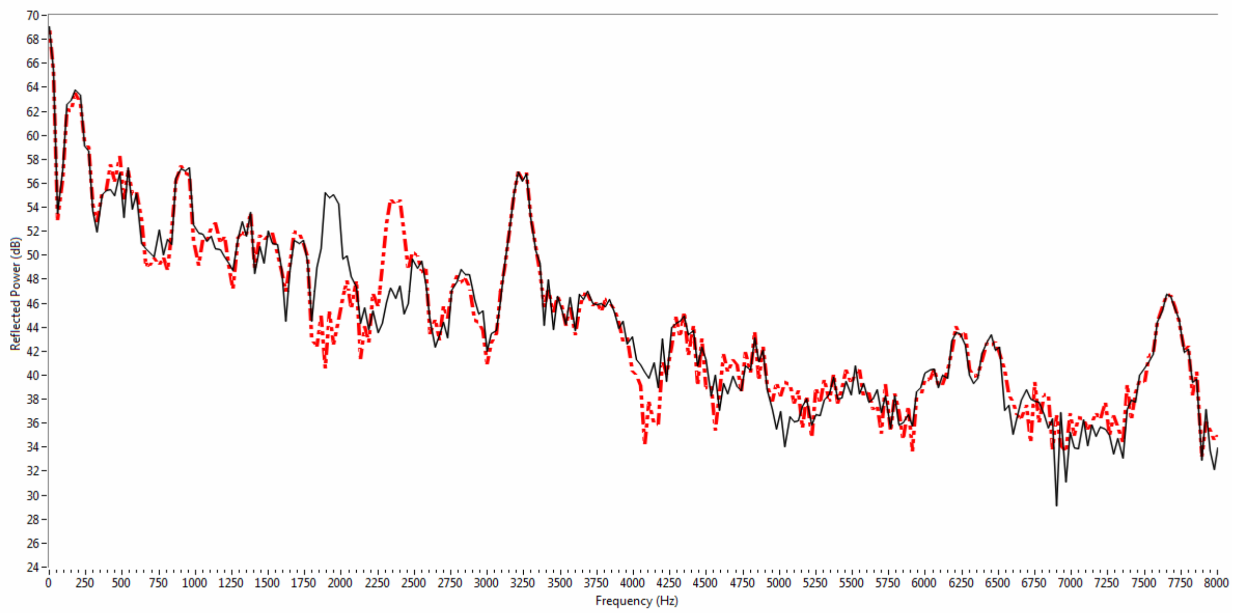
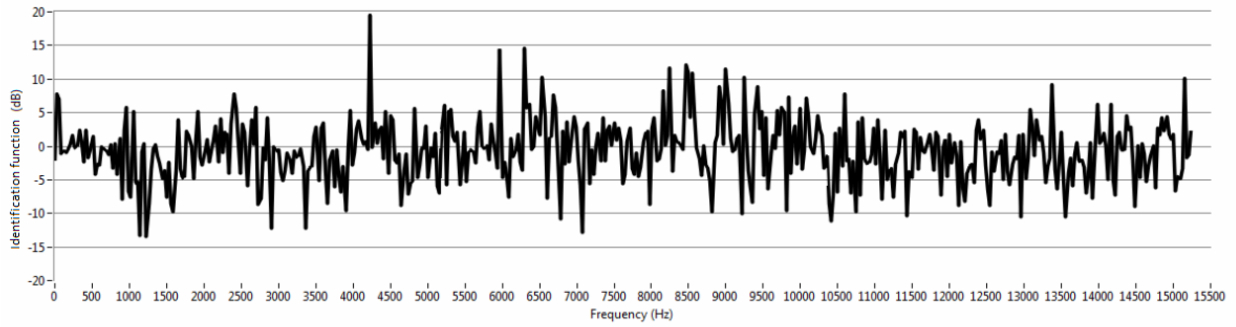
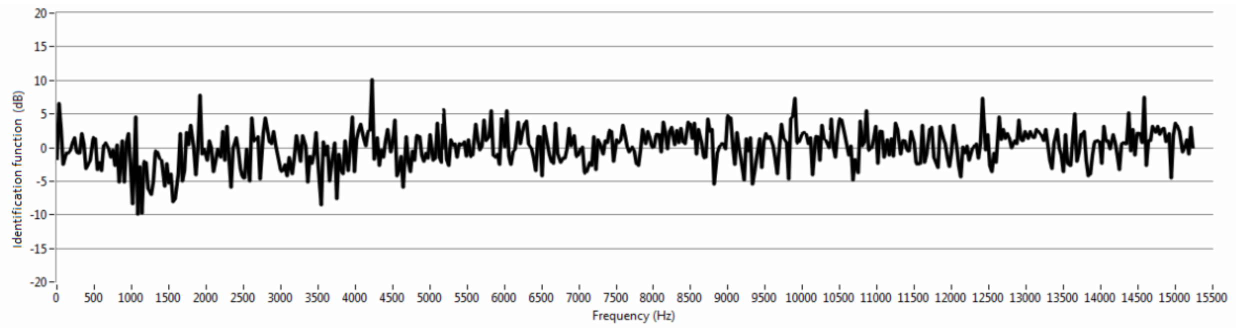


Fig.3. Spectra of clutter and moving targets (solid – up- spectrum, dashed – down- spectrum)

Taking into account aforementioned considerations, we can conclude that for non-coherent radars it is also possible to suppress the clutter, which will improve the potential of the system if the respective processing algorithm is applied. The obtained results are presented and discussed in [4]. The essence of the tested method is in comparison and suppression of the spectral peaks with the same frequencies. Actually, the method is simple enough and realizable, but there is not enough resemblance between the spectral peaks, caused by the system non-coherence and noise existence, that's why it is hard to get a desirable level of clutter suppression. Based on the considerations, that spectral differences are caused by the system non-coherence, it can be concluded that they will have a random character. The method of ensemble averaging of the random processes can be successfully used in this case as well. We have already done some preliminary estimation on that topic, and achieved results proving the reliability of the mentioned considerations. In order to describe properly, we introduce *an identification function* as the spectrum of point-by-point ratio of two sequentially measured periods. Such identification function of spectral components vs. frequency is shown in Fig. 4.



a)



b)

Fig.4. Identification function vs. frequency (a - without averaging, b - 10 times ensemble averaging)

3. Weather Conditions and Conclusion

The recent observations showed, that there is a dependency between the reliability of detection and the weather. Weather conditions have substantial influence on the quality of clutter suppression.

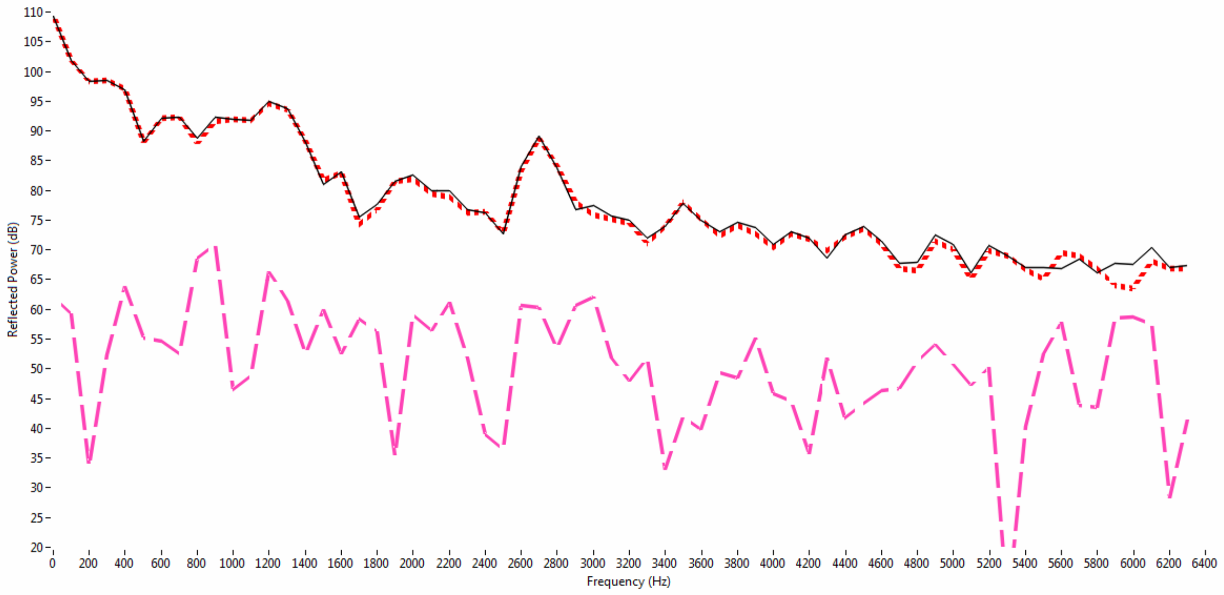


Fig. 5. Spectra of land clutter (solid – 1st period spectrum, points – 2nd period spectrum, dashed - difference)

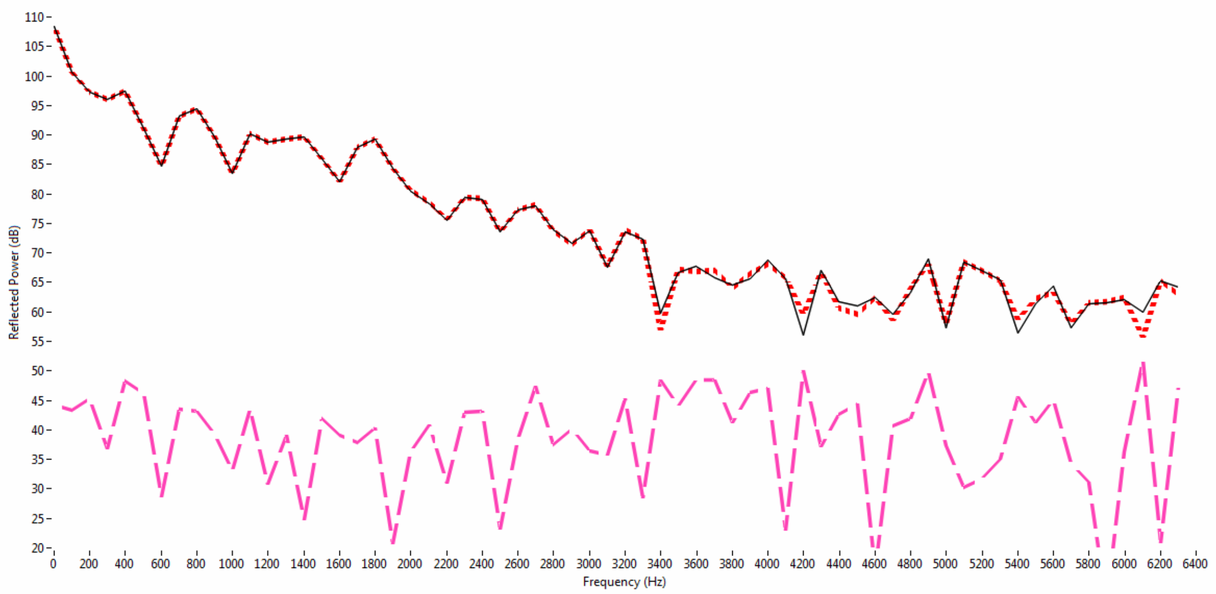


Fig. 6. Spectra of land clutter with a layer of 10 cm snow (solid – 1st period spectrum, points – 2nd period spectrum, dashed - difference)

It is well known that, ideally, the spectrum of the received radar signal must be invariant during LFM sawtooth periods, if there is no moving object in coverage, but really, they differ a little due to fading. FFT spectra and the respective difference have been counted during two adjacent periods. The weather dependent results are shown in Fig. 5 and Fig. 6.

It is obvious that snow coating significantly improves the situation and the difference of spectra in two adjacent periods is small enough. Probably, it is caused by the reduction of small-scale fading [6].

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LFM-CW ոչ-կոհերենտ ռադարներում տեղային օբյեկտներից անդրադարձած ազդանշանի ճնշման մի ալգորիթմ

Հ. Ավագյան

Ամփոփում

Ներկայացված է LFM-CW ռադարների համար տեղային օբյեկտներից անդրադարձած ազդանշանի ճնշման ալգորիթմ: Ներմուծված նույնականացման ֆունկցիայի միջոցով ձևակերպված են հաջորդական չափումների միջև առկա նմանությունները: Ցույց է տրված, որ ըստ անսամբլի միջինացումը թույլ է տալիս էականորեն պարզեցնել շարժվող թիրախների հայտնաբերումը:

Алгоритм подавления фона местных объектов в некогерентных РЛС непрерывного излучения с ЛЧМ

О. Авакян

Аннотация

Представлен алгоритм для подавления фона местных объектов в некогерентных РЛС непрерывного излучения с ЛЧМ. С помощью введенной функции идентичности сформулирована степень сходства в последовательных измерениях. Показано, что усреднение по ансамблю позволяет значительно упростить процедуру селекции движущихся целей.