# Increasing Of the Efficiency of Interference Suppression in mm-band Doppler Radars

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## Abstract

The statistical characteristics of terrain clutters backscattering in mm-band are presented. It is shown that the signals, reflected from deciduous trees are nonstationary in most cases. This phenomenon is due to high spatial resolution of mm-band radars. The influence of signal, reflected from vegetation, on MTI systems operation is analyzed.

## 1. Introduction

Usage of mm-band radars advantages allows us to solve variety of problems. The main one of those advantages is a high spatial resolution. Microwave radar, as a rule, works in noisy conditions: it receives signals, reflected from terrain. Detection of a moving target in terrain clutters is one of the major problems.

For solution of this problem a moving-target-indication (MTI) radar is used which allows detection of a moving object, such as an aircraft or vehicle. A difference in Doppler shift between terrain clutters and target is utilized there.

Papers [1-4] present review and analysis of energy spectrum of signals, reflected from trees and bushes in the special conditions: at different wind speeds and polarizations of direct electromagnetic wave. It is necessary to mention, that all of presented characteristics are obtained for the case of stationary noise. But for mm-band radar the noise may be inhomogeneous and nonstationary due to its high spatial resolution and relatively small time of data updates. Statistical characteristics of terrain clutters may be useful for evaluation of real efficiency of MTI systems, but this information is almost absent in the literature.

The purpose of this study is obtaining and analysis of experimental characteristics of terrain clutters in mm-band associated with the reflection from vegetation and evaluation of terrain clutters influence on efficiency of MTI systems.

## 2. Statistical characteristics of terrain clutter, obtained during experiment

For solving this problem the Doppler radar was constructed. Technical parameters of the radar are presented in table 1. Realizations of signal, reflected from different type of vegetation: grass, bushes, trees (birch, willow) at different wind velocity (1-10m/s) were obtained with this radar. Pretreatment and analysis of this data show that the level of signal reflected from bushes and grass is 10-20dB less than the signal reflected from the trees.

It is clear, that high level terrain clutters have a greater impact on the operation of the MTI systems, so in this work we will obtain and analyze only characteristics of signals reflected from trees at time intervals which are close to the time analysis of real radar.

We can see that spectrum, obtained on short time intervals (from hundredths to tenths of a second) have some features. The main feature of those spectrums is significant variability in time of their parameters: level of spectral components, bandwidth and shape of spectrum envelope. It is necessary to mention, that parameters variability was observed on frequency more than 500Hz which corresponds radial velocity more than 0.5m/s

As an additional parameter characterizing the signal which was scattered from vegetation we choose a cutoff frequency of spectrum ($F_{gr}$). This parameter is derived from the condition that instantaneous interference power at frequencies above $F_{gr}$ is equal or less triple power of the radar receiver noise.

Table 1.- Technical parameters of the Doppler radar

| Parameters | |
|---|---|
| operation signal | |
| Radiated signal | Continuous |
| Frequency | 140 GHz |
| Power | 0.6-1W |
| Bandwidth analysis of the Doppler frequency | 0.01-10kHz |
| Beam Width | |
| In azimuth plane | 6° |
| In elevation plane | 3° |

Using instantaneous signal spectrum we obtain the instantaneous interference power for observation time 0.13s and for frequency range 0.5 kHz - $F_{gr}$. The instantaneous interference power characterizes the radar cross section (RCS) of the observed terrain clutter. The absolute value of RCS is obtained by comparing levels of terrain clutter signal and the signal reflected from calibration reflector (ball).

The RSC and $F_{gr}$ are random variables, characterizing the interference from deciduous trees. To obtain these parameters the signal records with total length more than 100 minutes were analyzed. The example of random process realization (time dependence RSC and $F_{gr}$) is presented in fig. 1. This example show that the processes $\sigma(t)$ and $F_{gr}(t)$ are nonstationary.

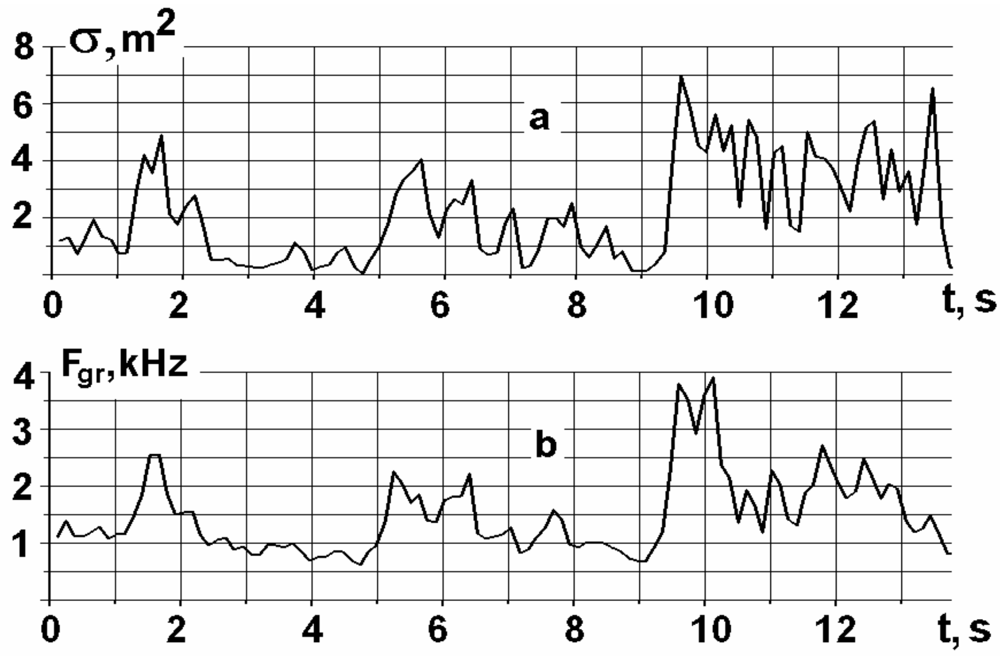


Figure. 1 - Random process examples: a) RCS of the terrain clutter; b) cutoff frequency of the instantaneous signal spectrum.

For random processes $\sigma(t)$ and $F_{gr}(t)$ for different realization time $T_r$ the coefficient of cross-correlation $R$, medians $\overline{\sigma(t)}$ and $\overline{F_{gr}(t)}$, standard deviations $\vartheta_\sigma$ and $\vartheta_F$, probability of exceeding the processes $\sigma(t)$ and $F_{gr}(t)$ of its average value $P_\sigma$ and $P_F$ are calculated. These data are presented in table 2. First of all, it should be noted that coefficient of cross-correlation ( $R$ ) does not go below 0.7 for all analyzing time. This fact indicates a strong statistical relationship between RSC and $F_{gr}$. It should be noted also that the processes $\sigma(t)$ and $F_{gr}(t)$ are asymmetric because the probabilities $P_\sigma$ and $P_F$ are less than 0.5. Deviations from average value to the smaller side have a larger probability and have larger amplitude than changes in larger side.

Table 2 – Statistical characteristics of the processes $\sigma(t)$ and $F_{gr}(t)$

| $T_r$, s | $R$ | $\overline{\sigma(t)}$, m$^2$ | $\overline{F_{gr}(t)}$, kHz | $\vartheta_\sigma$, m$^2$ | $\vartheta_F$, kHz | $P_\sigma$ | $P_F$ |
|---|---|---|---|---|---|---|---|
| 16 | 0,86 | 2 | 1,42 | 1,7 | 0,66 | 0,39 | 0,36 |
| 50 | 0,77 | 2,53 | 1,8 | 1,74 | 0,83 | 0,44 | 0,41 |
| 100 | 0,73 | 2,77 | 1,93 | 1,68 | 0,82 | 0,48 | 0,46 |

## 3. Influence of signal, reflected from vegetation, on MTI systems operation.

In this work we restrict ourselves on evaluation of the moving target indication (MTI) systems influence on SNR which is one of the main parameters for estimation of detection characteristics. The basic part of all MTI systems is a notch filter. The main function of this filter is suppression of interference signals with frequencies 0-$F_{p\max}$ and passing the information signal in frequency range $F_{p\max}$ - $F_{dM}$ , where $F_{p\max}$ is the maximum Doppler interference frequency, $F_{dM}$ is the maximum Doppler frequency of the information signal. Developers of warning MTI radars interests in constant false alarm rate (CFAR) [3]. CFAR is determined from SNR when the characteristics of interference are known.

In case of non-stationary interference we propose to use the probability (Q) of SNR at the filter output exceeding a certain level as an efficiency ratio of MTI system. This level of SNR is preliminary set to obtain necessary detection characteristics.

The notch filter parameters influence on Q-ratio are obtained using numerical modeling. We analyze the MTI systems with filters with fixed bandwidths (1.5kHz-∞), (3kHz-∞), or a filter with variable bandwidth. The results of modeling are presented on fig.2.

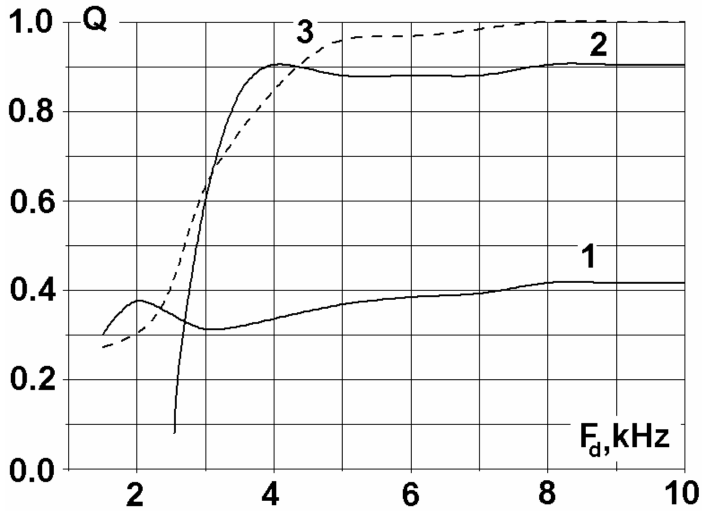


Figure 2. – MIT system coefficient of efficiency dependence of target Doppler frequency.
1-HPF with cutoff frequency $F_{qoff}$ 1.5 kHz, 2 - 1-HPF with cutoff frequency $F_{qoff}$ 3 kHz; HPF with variable cutoff frequency

By analyzing these results we can evaluate the filtering efficiency for different target radial speed. The high pass filter (HPF) with cutoff frequency $F_{qoff}$ 1.5 kHz works successfully with low speed targets. However, efficiency of this filter for all targets, which have a Doppler frequency ($F_d$) up to 10 kHz does not exceed 40%. Consequently, this filter can work effectively during only 40% of time. Increasing the cutoff frequency up to 3 kHz improves the efficiency ratio up to Q=0.888, when target Doppler frequency exceeds 3 kHz. However, if the target Doppler frequency decreases below than 3 kHz, the efficiency ratio tends to zero. So, this MTI system cannot be used for detecting low speed target. Presented dependences allow concluding that HPF with low cutoff frequency can provide required SNR only for targets with low Doppler frequency. The latter frequency is defined by the lowest spectral component of nonstationary interference (in our case: less than 1.5 kHz). Increasing the cutoff frequency leads to the fact that low-speed target becomes invisible

HPF with variable cutoff frequency has efficiency $Q$ not worse than HPF with $F_{qoff}$=1.5 kHz for low speed target detection. For high speed target with $F_d \geq 4$ kHz considered HPF has very high efficiency (Q=0,9). Small ripples on the curves of efficiency $Q(F_d)$ can be explained by irregularities of the filter bandwidth. They are determined by the filter model, used in numerical simulations.

## 3. Conclusion

Performed investigation allows obtaining the following main results:

1. In mm-band the signals, reflected from deciduous trees are nonstationary in most cases. This phenomenon is due to high spatial resolution of mm-band radars. It can be manifested by a variation of reflected signal power and cutoff frequency of its Doppler spectrum. Mentioned variables have high cross-correlation.

2. Application of the HPF with flexible band-pass gives acceptable performance for low-speed targets and significantly increases it for high-speed targets. Algorithm controlling the filter bandwidth has to imply the statistical relation between instantaneous interference power and cut-off frequency of the interference Doppler spectrum. It is necessary to mention that by proper choosing the filter frequency characteristics we can also obtain whitening the incoming interference spectrum.

## 4. References


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