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# MODELING OF BISTATIC RADAR CLUTTER

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*Summary: The bistatic radar forms a basic part of multistatic radar systems for Air Traffic Control. The effort in this article is to provide the inside and make basis for future research of the bistatic radar clutter. There is a clutter scenario defined, and a very general geometry is used. For that the bistatic radar clutter power equation is derived and used for computation of some of interesting parameters such as a bistatic radar effective clutter cross section, a mean clutter power and clutter reflectivity. The developed model for the bistatic clutter is demonstrated on signals of a FM radio receiver base station.*

*Key words: bistatic radar clutter, clutter geometry, clutter cross section RCS.*

## INTRODUCTION

Passive coherent location, in which the bistatic radar has a significant role, represents an old concept (the first successfully employed radar more than 70 years ago was in fact a bistatic one). With the new computing facilities it represents a new approach to the radio detection and ranging While many publications has been written (5), (6), (4) aso., on the monostatic radar clutter in the case of bistatic radars the area of clutter research is relatively new and there has not been many articles published yet. In this paper we introduce a very general way of bistatic radar clutter representation to build a base for the future research in this field. First we should define the clutter scenario geometry and derive bistatic radar clutter power equation. Further on we demonstrate the results of the software model simulation for a real parameters and geometry.

## 1. SYSTEM DEFINITION

### 1.1 The bistatic radar clutter equation and geometry

The bistatic scenario (Fig.1) consists of a spatially separated transmitter and receiver antennas at the foci of an ellipse in the distance $L$ (baseline). The receiver antenna receives wanted echoes (targets), unwanted echoes (clutter) and the originally transmitted direct signal. Then by TDOA (time difference of arrival) method bistatic range $R_B$ of the target (elliptic distance) and its radial velocity from the Doppler processing (2) can be estimated. The minimum separation between two targets of similar reflectivity (to be recognized) in the bistatic range is a minimum resolution range, denoted by $dR_B$ (1):

$$dR_B = \frac{c}{2B} = \frac{c\tau}{2} \qquad (1)$$

Where:

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- $c$ is speed of light,
- $B$ is effective signal bandwidth,
- $\tau$ is compressed pulsewidth.

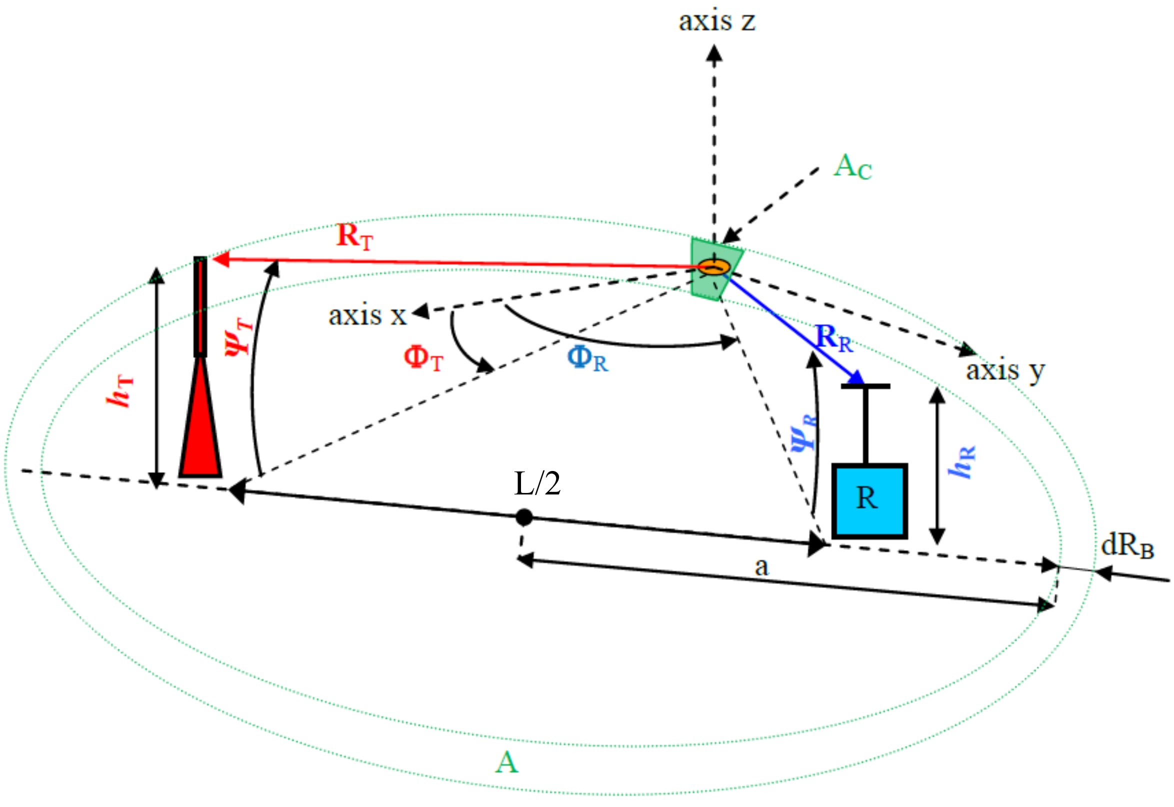

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Fig.1 – Basic bistatic clutter model geometry and Cartesian coordinates. A$_C$ is a centre of the clutter cell. R is the receiver, T is the transmitter

On the ground reference plane, tangential to the Earth's surface at $Ac$, the elliptic resolution range cell (resolution belt) is defined by its inner ellipse with the semi-major axis $a$ and the outer ellipse with the semi-major axis $a + dR_B$. The whole elliptic resolution belt area $A$ can be divided in elemental parts $dA$ with clutter in each of them we assume a constant clutter reflectivity $\sigma_0$ (scattering cross section per unit area) (6). The distance to center ellipse of the each resolution belt is supposed as:

$$R_C \equiv 2(a + \frac{dR_B}{2}) \equiv R_T + R_R \tag{3}$$

Where $R_T = \left|\vec{R}_T\right|, R_R = \left|\vec{R}_R\right|$ are the distances from the transmitter or the receiver antenna to the clutter element $dA$ center on the surface, respectively. Then if we assume omnidirectional transmitter and receiver antennas we can say that the average power $P_C(R_C)$ received from one resolution belt (on the receiver circuits) is a sum of powers scattered from each elemental area $dA$ (6). Thus:

$$P_C\left(R_C\right) = \frac{P_T G_T G_R \lambda^2}{\left(4\pi\right)^3 L_S} \int_A \frac{\sigma_0}{R_T^2 R_R^2} dA \tag{2}$$

Where:

- $P_T$ is the transmitted power,
- $G_T$ is the transmitter antenna gain,
- $G_R$ is the receiver antenna gain,
- $\lambda$ is the signal wavelength,
- $L_S$ are the system losses.

If we suppose the product $(R_T R_R)^2$ and the scattering coefficient $\sigma_0$ to be approximately constant within a relatively small clutter area $A_C$ we can estimate the average power $P_C$ of the particular resolution belt area $A_i$ as:

$$P_C\left(R_{Ci}\right)=\frac{P_T G_T G_R \lambda^2}{(4\pi)^3 L_S}\sum_{j=1}^{N}\frac{\sigma_{0i}(x_j,y_j,z_j)}{R_{Ti}^2(x_j,y_j,z_j)R_{Ri}^2(x_j,y_j,z_j)}A_{Ci}(x_j,y_j,z_j) \quad (3)$$

Where:

- $(x_j, y_j, z_j)$ are the Cartesian coordinates of the $j$-th clutter area,
- $i$ is the index of the $i$-th resolution belt area $A_i$.

## 1.2 The bistatic land clutter cross section

To be able to use some simplified model of reflectivity we assume that each land clutter area $A_C$ provides isotropic scattering. Then if we use the constant-$\gamma$ model for the monostatic radar (5) the model of the bistatic land clutter cross section per unit area $\sigma_0$ (clutter reflectivity) will be:

$$\sigma_0 = \gamma \sin(\psi_T) \quad (4)$$

Where:

- $\gamma$ is a normalized reflectivity parameter,
- $\psi_T$ is the grazing angle from transmitter antenna to the center of the clutter area Ac.

Barton in (5) suggested values of the $\gamma$ for farm land -15dB and for woodened hills about -10dB.

## 1.3 The effective clutter cross section

It is useful to define the effective radar cross section of the clutter area Ac as:

$$\sigma_{ef} = \frac{(4\pi)^3 P_R L_S}{\lambda^2 P_T G_T G_R} R_T{}^2 R_R{}^2 \quad (5)$$

# 2. MODEL DEMONSTRATION

## 2.1 Parameters setting

To demonstrate model’s performance it was chosen the FM radio receiver base – station (VHF band) with a circular antenna array, consisting of 8 dipole antennas, each equipped with its own receiver. It is a usual measurement scenario used for inst. in (7):

Simulation parameters for the FM band evaluation:

- Transmitted power $P_T$ = 10kW,
- Transmitter antenna gain $G_T$ = 1,
- Receiver antenna gain $G_R$ = 1,
- Carrier frequency (VHF Band) $f_C$ = 100 MHz,
- Wavelength $\lambda$ = 3m,
- Effective bandwidth $B$ = 50 kHz
- Resolution belt width $dR_B$ = 3km.
- Baseline $L$ = 70km
- The transmitter antenna height $h_T$ = 1343m.

## 2.2 The simulation results

The first simulation result shows the effective clutter cross section $\sigma_{ef}$ as a function of spatial configuration of the transmitter antenna T and receiver R.

In the Fig.2 it can be seen that the maxima of $\sigma_{ef}$ are near the center at the closest resolution belt to the transmitter and the receiver antennas. From the nature of the $\sigma_{ef}$ estimation formula minimum can be found near the T and R locations.

For a better notion of $\sigma_{ef}$ nature there is a 3D line plot in the Fig. 3. Here we may see the maximum value at the center of the blue resolution range belt center ellipse of 76 dBm$^2$. Also minimum value is nearest to T and R positions with magnitude about 56 dBm$^2$.

In the Fig. 4 there is plotted the clutter cross section per unit area using constant-$\gamma$ model $\sigma_0$. There can be seen a strong dependence of this model on a grazing angle $\psi_T$. Also the maxima of $\sigma_0$ are closest to the position of the transmitter antenna. Here the maximum value has magnitude about -16 dBm$^2$ and minimum value is furthest from T and R locations with magnitude about -30 dBm$^2$.

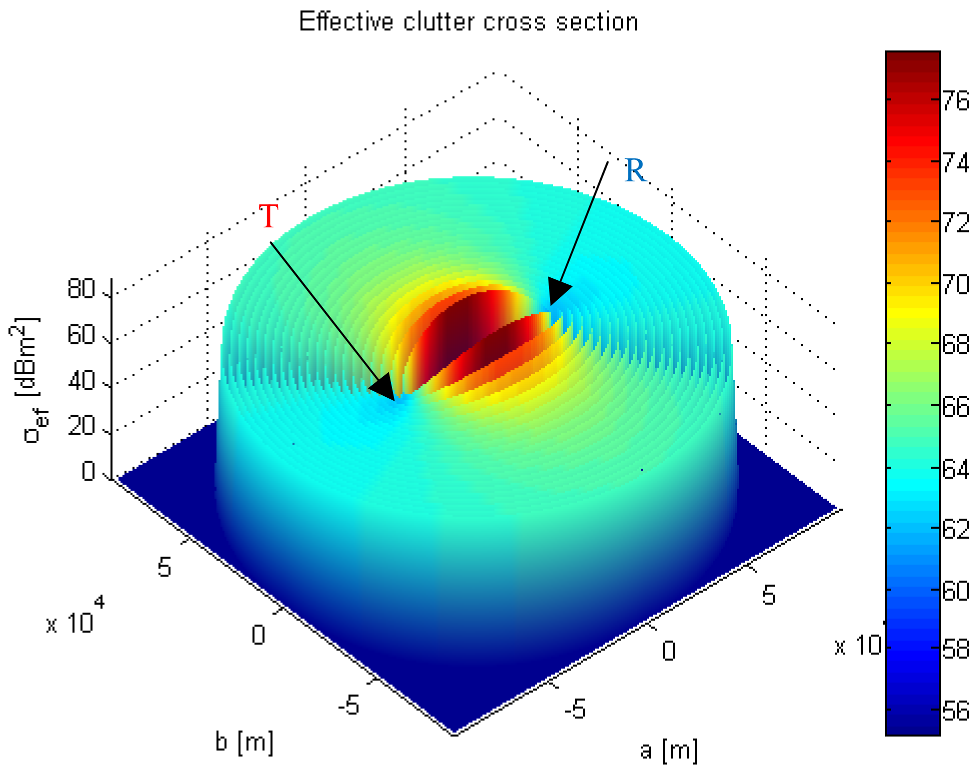

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Fig.2 – Surface plot of the effective clutter cross section

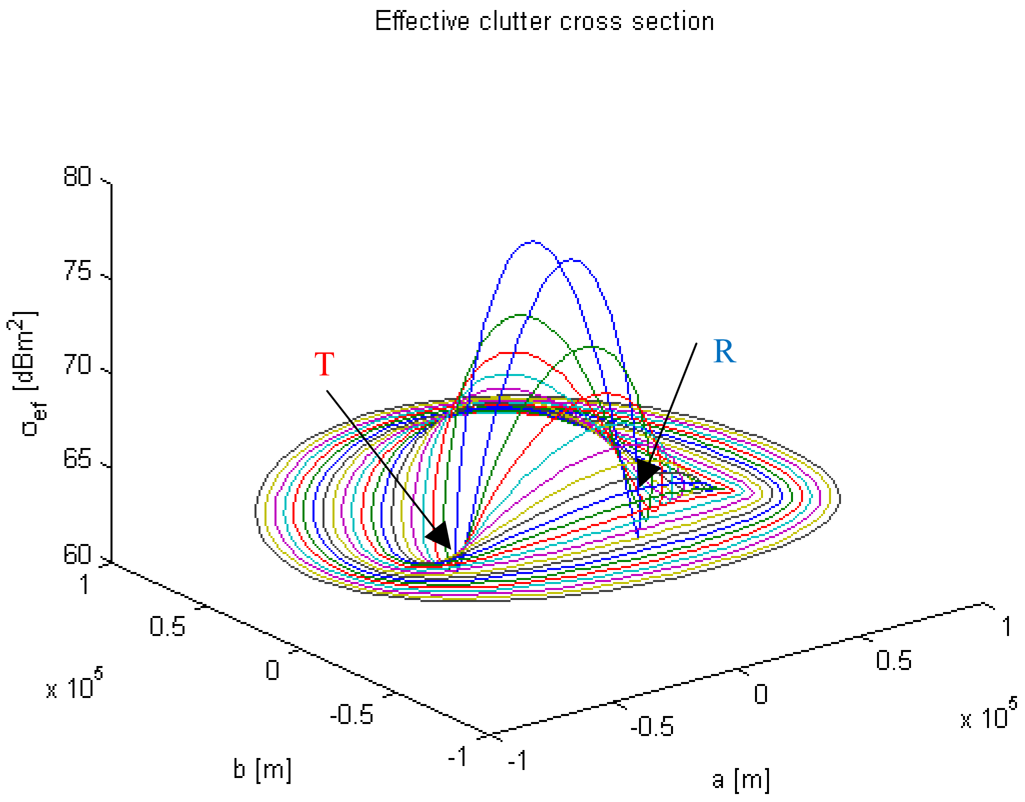

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Fig. 3 – 3d plot of the effective clutter cross section

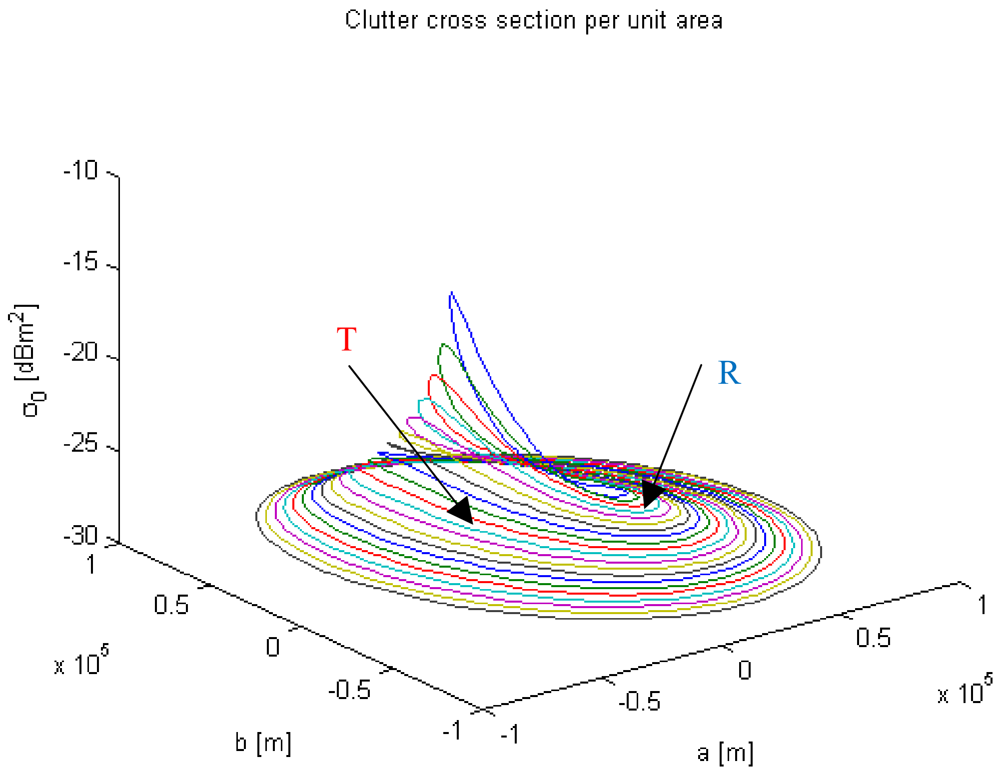

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Fig. 4 – 3d plot of the clutter cross section per unit area

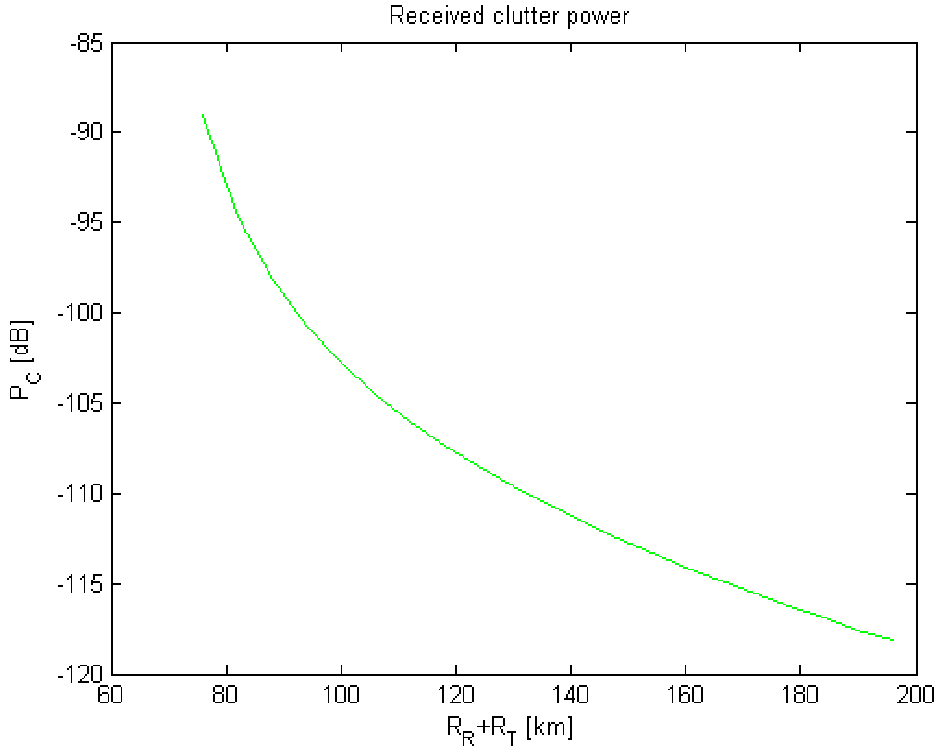

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Fig. 5 – Average power received on the receiver antenna

Fig. 5 shows the average power $P_C$ get on the receiver as a function of the distance $R_C$ to the center ellipse of the each resolution belt $A_C$. This graph could be used to demonstrate how fast the average clutter power disappears with the distance $R_C$ from T and R. In this graph also can be seen that the average power $P_C$ get on the receiver disappears exponentially in selected distance interval. It falls about 30 dB with distance 130km. The maximum value of $P_C$ is -88dB for the distance $R_C$ of 76km and the minimum value of average power $P_C$ is about -118dB in the elliptic distance $R_C$ of 196km.

## CONCLUSION

The bistatic scattering coefficient $\sigma 0$ is in general a function of grazing angles $\psi T$, $\psi R$, azimuth angles $\theta T$, $\theta R$ and location. However no analytical exact model exists till now.

There are many books, measurements and models dealing with the monostatic radar land clutter (5), (6), (4), but there has been relatively little written about the bistatic land clutter. In case of the bistatic clutter due to more complex geometry more parameters are involved. In the future we will follow using the statistical approach. However the presented model is suitable as a basis for the future research and provides very general inside in the more specific scenario.

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