Optimization of STC for Collecting Terrain Information

Sang-Ik Lee [1], Byeong-Yong Park [1], Soon-Gyu Yi [1], Seong-Ook Park [1]
[1] Department of Electrical Engineering, KAIST
119, Munjiro, Yuseong-gu, Daejeon, 305-732, The Republic of Korea, marshal2@kaist.ac.kr

1. Introduction

RADAR system can be used in low altitude for surveillance, terrain information acquisition and other purposes in commercial or military fields. One big problem with the RADAR system is the large backscattering signals from target or clutter. These will make the receiver saturated or degenerated. Sensitivity Time Control is one of the methods to overcome this problem. The STC also has other effect such as rejection of the clutter because RADAR normally distinguish targets depending on whether the received signal's value is above the specific threshold value or not, and STC can make clutter signal smaller than the threshold value. Therefore system designer should choose proper STC performance according to the clutter.

This paper focuses on design of optimized STC performance for RADAR which is used for gathering terrain information within the RADAR detection range such as mountains, hills, buildings or man-made structures. In this case, ground is the most interesting clutter. Therefore STC should be designed from received ground power according to the range. This STC is also applied in actual non-coherent RADAR system to measure the surrounding terrain to compare simulation and actual performance.

2. RADAR System

In this paper, non-coherent RADAR system shown in Fig. 1 is used for applying STC. The peak power of the transmitter is 4kW. The pulse is mono-tone and has 65ns pulse length. The PRF is 3000Hz. Slotted waveguide array antenna is used and its performance is shown in Table 1. Sensitivity of the RF receiver is -60dBm and dynamic range is 50dB. For the isolation between the transmitter and the receiver, the receiver turns off for 0.492μs and STC operates according to PRI repeatedly. IF receiver has a logarithmic detector in order to translate dB-scale into voltage (Video signal). STC circuit is located after the logarithmic detector in IF frequency and it can make various waves to vary the IF gain. 20dB attenuation occurs per 1V(control voltage) increase of STC wave in this system.

3. Design of STC

As mentioned above, STC is used to prevent the receiver from saturation due to nearby target or clutter. The receiver designer should choose proper suppression level. If the suppression level is high, target signal is attenuated severely. If the suppression level is low, high clutter signal is received.

3.1 Radar Equation for area scattering

To determine the STC, there are several things to be considered. We decide the curve according to ground scattering electromagnetic power. In general, the RADAR equation is used to estimate the backscattered electromagnetic power [1] :

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 L_s L_a R^4} \tag{1}$$

where P_r is received signal power, P_t is transmitted power, G is antenna gain, λ is wavelength, σ is radar cross section, L_s is system loss factor, L_a is atmospheric attenuation and R is range. To consider scattering area, two cases which depend on whether the range extent of the scatters contributing to the echo is limited by the antenna elevation beamwidth or by the range resolution are considered [1]. The boundary between the two cases is

$$\text{Beam-limited : } \frac{\Delta R}{R_0}\tan\delta > \Phi_3 \tag{2}$$

$$\text{Pulse-limited : } \frac{\Delta R}{R_0}\tan\delta < \Phi_3 \tag{3}$$

where ΔR is range resolution, δ is grazing angle and Φ_3 is vertical 3dB-beamwidth. Pulse-limited case in this paper considers radiation pattern, position and the grazing angle of the antenna. Thus the received power is

$$P_r = \frac{P_t G^2 \lambda^2 \sigma_0 \Delta R \theta_3}{(4\pi)^3 R^3 L_s L_a(R\ )\cos\delta} \tag{4}$$

, where θ_3 is horizontal 3dB-beamwidth.

3.2 Radar Cross Section

In equation (4) the radar cross section σ_0 for ground is determined to get the value of the received power. Usually constant-γ model is adopted. However it is not proper model at grazing angles close to 0˚. There are several other scenarios to measure the radar cross section from various terrain, weather, grazing angle, frequency and antenna polarity. Reasonable value is adopted among these scenarios considering the antenna's polarity (horizontal), general town ground characteristic which consist of soil, vegetation, concrete or asphalt and grazing angle (below 12.5˚ because of the antenna's vertical beamwidth where the antenna is located parallel to the ground and plain ground). In this paper, radar cross section is set to approximate -20dB [2].

3.3 STC control signal

Using equation (4), received signal of ground backscatter can be induced according to range. Atmospheric attenuation can be written as

$$L_a(R)(dB) = \alpha R / 500 \tag{5}$$

Considering an X-band in sea level altitude, $\alpha = 0.02dB$ (this is small value). System loss factor (L_s) is also very tiny level. Thus two losses are negligible. Grazing angle (δ) is set to 12.5˚. The simulation result is shown in Fig. 2. From this result the STC curve can be induced. Since the receiver turns off for 0.492μs according to PRI repeatedly (It means that the RADAR cannot see the distance under 73.8m.), STC is actually operated after 0.492μs. And it is also determined how much the signal is attenuated and this is the level where nearby ground clutter power becomes similar to far one. The designed STC is shown in Fig. 3. It can be known that the received signal power varies as R^{-3} from Fig. 2 and 3 since the results are derived from equation (4).

4. Experiment and Results

The antenna and RADAR system is located on the top of the roof whose height is 30m to measure the terrain backscattering signal. The region for experiment is shown in Fig. 4. The range is limited by less than 4.5km because the mountains and hills make shadow areas and these areas's backscattering signal cannot be acquired. The signal is measured per 1˚ by rotating the antenna and the total area measured is 120˚. The antenna's horizontal 3-dB beamwidth(1.15˚) is considered. STC is varied to confirm the effect of STC and to compare the results. In this paper, 6 different cases of STC are used for experiment. The results of the measurement are shown in Fig. 5 - 10. It can be shown that the STC 3 which is similar to the designed STC curve has the best effect of suppressing nearby clutter and makes nearby target to stand out.

5. Conclusion

The STC is designed for optimization of getting terrain backscattering signal using RADAR system. To suppress the ground clutter power according to the range, the radar equation which is induced for pulse-limited area scattering case is used. Finally, STC which varies by R^{-3} can be designed for standing out nearby target. It is important to design STC to enhance RADAR system performance.

Acknowledgments

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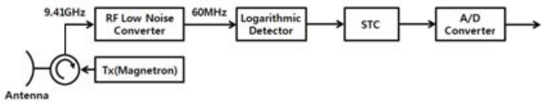

Figure 1: Non-coherent RADAR system

Table 1: Antenna Performance

Antenna Gain	29.56 dB
Polarity	Horizontal
Azimuth Beamwidth	1.15˚
Vertical Beamwidth	25˚

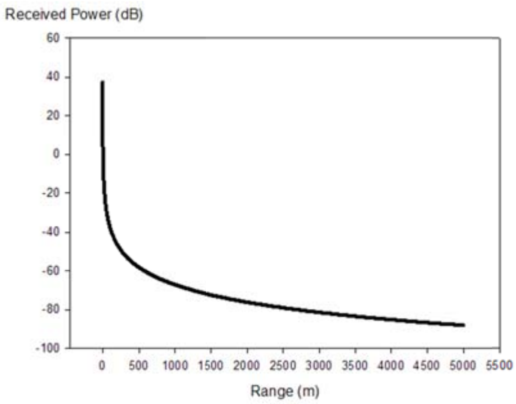

Figure 2: The simulation of received power according to range using equation (4)

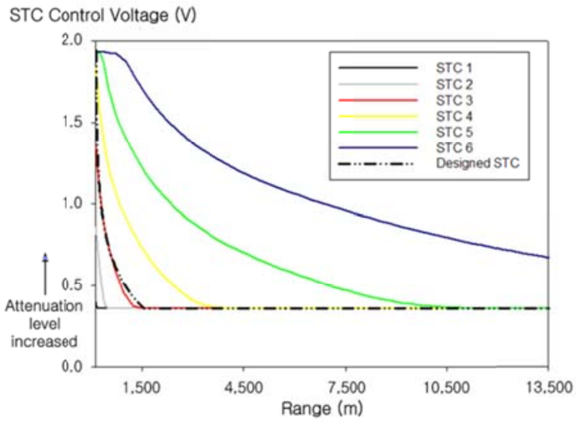

Figure 3: Designed STC and various STC for experiment

Figure 4: Experiment Area (Yuseong-gu, Daejeon) [5]

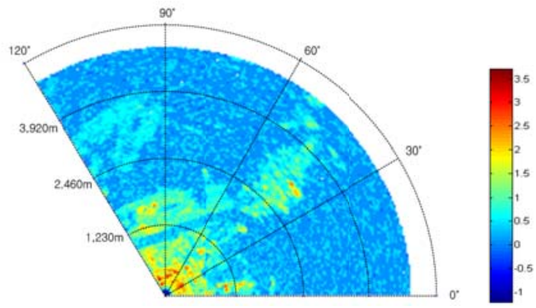

Figure 5: Video signal(Voltage-domain) of STC 1

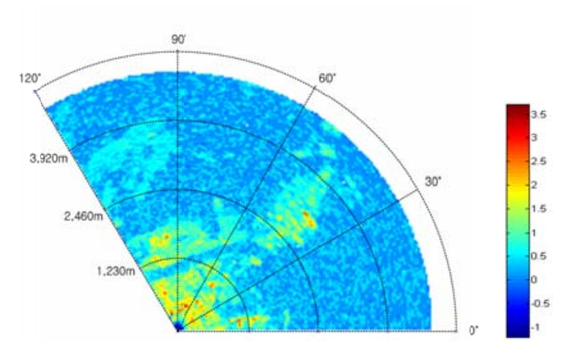

Figure 6: Video signal(Voltage-domain) of STC 2

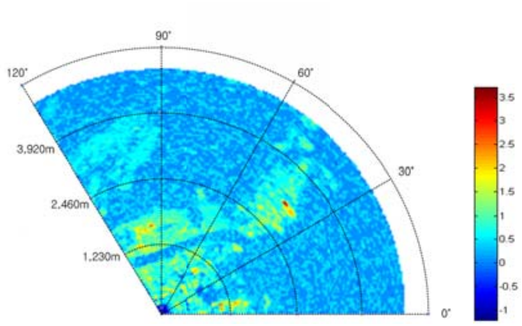

Figure 7: Video signal(Voltage-domain) of STC 3

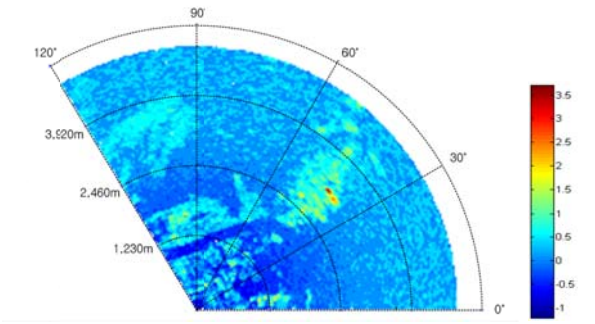

Figure 8: Video signal(Voltage-domain) of STC 4

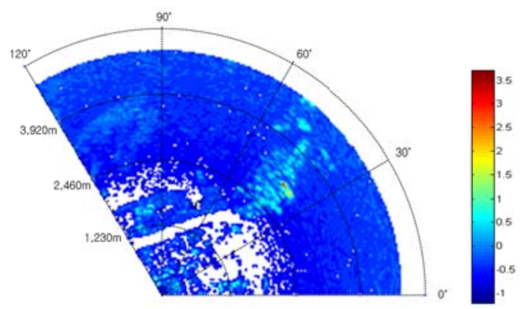

Figure 9: Video signal(Voltage-domain) of STC 5

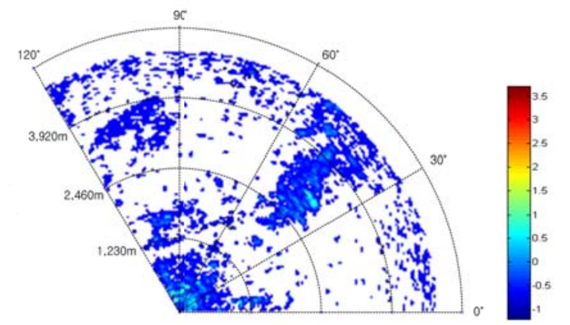

Figure 10: Video signal(Voltage-domain) of STC 6

References

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