Code Sequence Selection for SAR Radiometric Calibration[1]

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Abstract

It is an important significance for SAR radiometric calibration accuracy to select a proper code sequence about active coded transponder (ACT), in the process of active coding radiometric calibration using synthetic aperture radar (SAR). And m sequences, Gold sequences and random sequences are studied. Simulation experiments with the compression of SAR azimuth signals are carried out.

Keywords: Synthetic Aperture Radar (SAR), Active Coded Transponder (ACT), Radiometric Calibration, Cross-correlation

The principle of Active Encoding of Radiation Calibration

Figure 1 shows the flowchart of active coding radiometric calibration. When SAR moving along azimuth direction, the transmitted signal **1** is received by the ACT_k on the ground at the starting point s_0 of a synthetic aperture length. Then random code sequence in the ACT modulates the transmitted signal **1** using 0/π phase. Finally, the signal **2** is reflected to the SAR by the transmitting antenna in the ACT. After the first cycle of SAR transmitting signal, due to the movement of SAR, SAR would transmit another signal at the beginning of the second repeat cycle s_1.

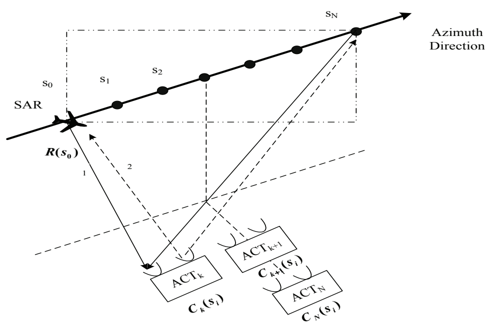

Fig.1. Flowchart of active coded transponder

Correlation Property of Code Sequence

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The azimuth compression reference signal is generated; the cross-correlation processing of the decoded signals is carried out. According to the above three kind of situations, the cross-correlation processing results are as follows:

Case 1: when using single ACT, we can get the autocorrelation values.

$$r_{a,m1}(l)=\sum_{i=-\infty}^{+\infty}\exp[-\frac{j4\pi R(s_i)}{\lambda}]\times\exp[-\frac{j4\pi R(s_{i+l})}{\lambda}] \quad (1)$$

Case 2: when using multiple ACT, the cross-correlation values between the signals of ACT.

$$r_{a,m2}=\sum_{i=-\infty}^{+\infty}\exp[-\frac{j4\pi R(s_i)}{\lambda}+jC_k(s_i)\pi-jC_j(s_i)\pi]\times\exp[-\frac{j4\pi R(s_{i+l})}{\lambda}] \quad (2)$$

Case 3: similarly, we can get the cross-correlation values between the signal of ACT and the signal of background clutter.

$$r_{a,b}=\sum_{i=-\infty}^{+\infty}\exp[-\frac{j4\pi R(s_i)}{\lambda}-jC_j(s_i)\pi]\times\exp[-\frac{j4\pi R(s_{i+l})}{\lambda}] \quad (3)$$

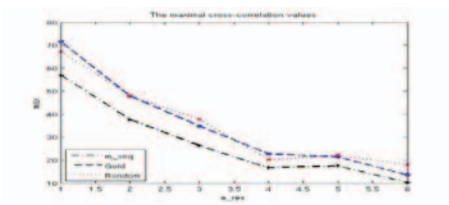
From equation (2) and equation (3), we can conclude that the cross-correlation values of different types of code sequences $C_k(s_i)$ (**m**-sequence, Gold-sequence and random sequence) must not be the same. What is more, there could be an optimal code sequence which can make cross-correlation values between the signals of different active coded transponders minimal in **Case** 2, namely the mutual disturbance between different active code transponders is the smallest.

Simulation: Correlation Simulation

Table 1 Number of m Sequence

Register Bits	6	7	8	9	10
M-Seq Num	6	18	16	48	60

In this paper, simulation experiments use m sequence whose number is as shown in table 1. Each experiment has been conducted 100 times, and the maximum, the minimum and the average of cross-correlation values has being statistically treated. The specific results are as follows:



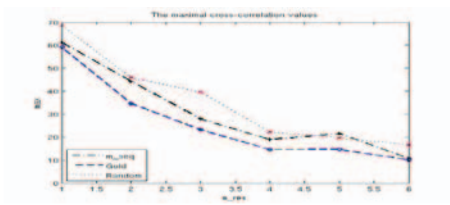
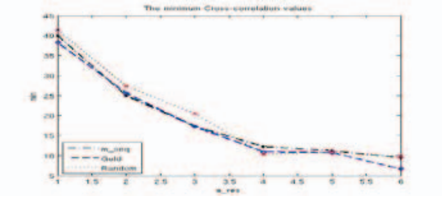


Fig 2: Between background and transponder Fig 3: Between transponders



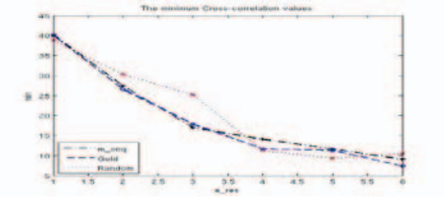
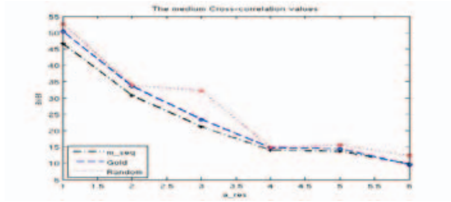


Fig 4: Between background and transponder Fig 5: Between transponders



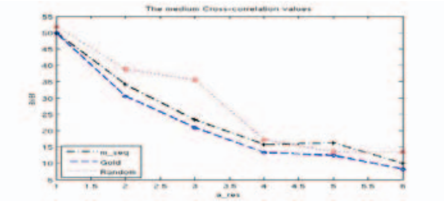
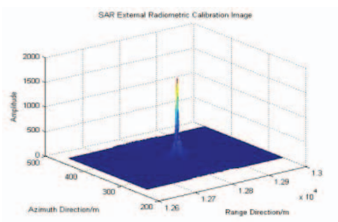


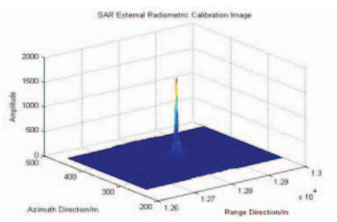
Fig 6: Between background and transponder Fig 7: Between transponders

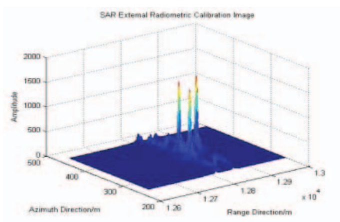
From Figure 2, Figure 3, Figure 4, Figure 5, Figure 6 and Figure 7, as for the cross-correlation values between the signal of active coded transponder and the signal of background clutter, **m** sequence is the best, but the difference of cross-correlation values between **m** sequence and Gold sequence is not large; as for the cross-correlation values between the signals of different active coded transponders, Gold sequence is the best, which depends on the good mutual correlation characteristic of Gold sequences. Considering the number of effective code sequences, Gold sequence is much better than **m** sequence.

Simulation: SAR Radiometric Calibration Image Simulation

We can draw a conclusion from above correlation simulation experiments that optimal code sequence is not invariable when using single ACT or multiple ACTs. In this section, the above conclusion would be further confirmed by SAR radiometric calibration image simulation. In our experiment, images resolution is 2.5m×5m; velocity of radar is 180 m/s; synthetic aperture time T_{syn} equals to 4s; we take three ACTs as example of multiple ACTs. SAR images for radiometric calibration using different code sequences are shown as follows.

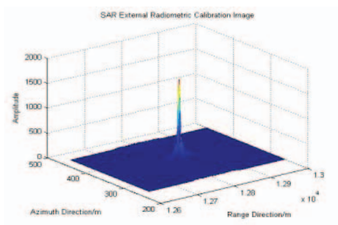


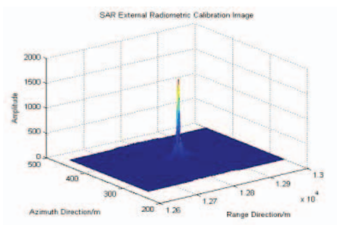


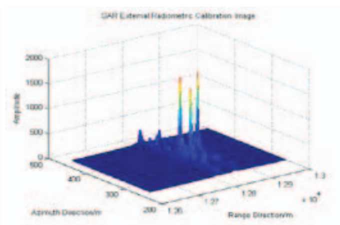


(a) (b) (c)

Fig 8:SAR images for radiometric calibration with m sequence, (a) Image of single ACT without noise, (b) Image of single ACT with SCR=20dB, (c) Image of multiple ACTs with SCR=20dB

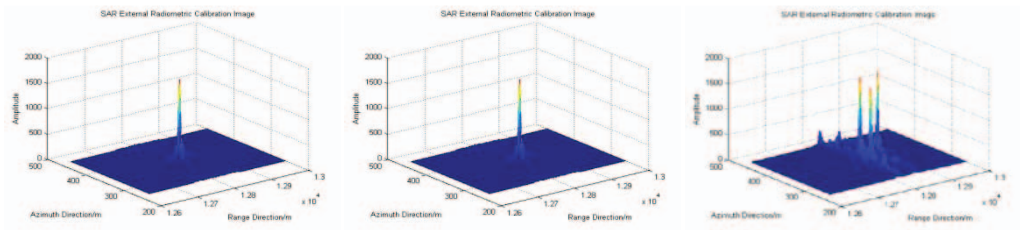






(a) (b) (c)

Fig 9:SAR images for radiometric calibration with gold sequence, (a) Image of single ACT without noise, (b) Image of single ACT with SCR=20dB, (c) Image of multiple ACTs with SCR=20dB



(a) (b) (c)

Fig 10:SAR images for radiometric calibration with random sequence, (a) Image of single ACT without noise, (b) Image of single ACT with SCR=20dB, (c) Image of multiple ACTs with SCR=20dB

Table 2 SAR radiometric calibration accuracy with three code sequence

SCR(dB)		0 (single ACT)	20 (single ACT)	20 (multiple ACTs)	MCR	
					single ACT	multiple ACTs
Average of peak-values	M sequences	1720.5	1717.7	1658.1	0.16%	3.63%
	Gold sequences	1576.9	1581.3	1554.2	0.47%	1.44%
	Random sequences	1667.9	1686.7	1751.6	1.13%	5.02%

From Table 2, it can be seen that it is compatible with above correlation simulation. If single ACT works, MCR of m sequences is smallest which means the change of SAR radiometric calibration image maximal value is more subtle, so **m** sequence is the best. If multiple active coded transponders work, MCR of Gold sequences is smaller than others which means the change of SAR radiometric calibration image maximal is much more subtle, Gold sequences is much better than **m** sequence and Random sequences.

Conclusion

The choice of ACT code sequence has being studied in detail. At different azimuth resolutions of SAR, the correlation property of **m** sequences, Gold sequences and random sequences has been analyzed by means of the simulation computation and SAR radiometric calibration images are simulated. A method to choose code sequence is proposed according to the results of simulation experiments.

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