RADARSAT-2 Application Look-Up Tables (LUTs)

Prepared By: MDA Technical Staff

Summary: This note describes the Application Look-up Tables (LUTs) that are used to scale the pixel values in RADARSAT-2 products. A selection guide is included to assist users when choosing the LUT to be used for product generation.

13800 Commerce Parkway
Richmond, B.C., Canada, V6V 2J3
Telephone (604) 278-3411
Fax (604) 278-2117

CHANGE RECORD

ISSUE	DATE	PAGE(S)	DESCRIPTION
1/0	July 31, 2008	All	First Issue
1/1	Oct. 30, 2009	All	Updated to include LUT selection guides.
1/2	Apr. 24, 2014	All	First Issue, Second Revision Added following application LUTs: • Point-Target-1 • Calibration-2 • Ice-2 • Ship-1 • Ship-2 • Ship-3 Added 8-bit application LUTs. Added RADARSAT-2 wide beam modes to application LUT selection guide.
1/3	Oct. 16, 2015	All	Updated for Ocean Surveillance and Ship Detection beam modes. Updated for SLC products. Updated to recommend generally darker LUTs, as quantization of dark targets has generally been less of an issue than saturation of bright targets.
1/4	July 22, 2016	All	Clarified how use of LUTs differs with product type (georeferenced detected vs SLC vs geocoded; 16-bit vs 8-bit).

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1 RADARSAT-2 APPLICATION LUTS

This note explains the Application Look-up Tables (LUTs) that are used for scaling RADARSAT-2 detected products. LUTs are used by the SAR processor to scale the pixel values at the end of image formation processing into the 16-bit (or in some cases 8-bit) dynamic range of the pixel values in RADARSAT-2 products.

Different LUTs are available to improve the usage of this limited dynamic range for specific applications. Some LUTs also compensate for range dependent changes in backscatter response of the target of interest, such that the resulting image is visually consistent from near to far range.

The Application LUT is selected by the user at the time the product order is created. The SAR processor then uses the selected LUT to scale the image pixel data when creating the RADARSAT-2 Product. This is depicted in Figure 1-1.

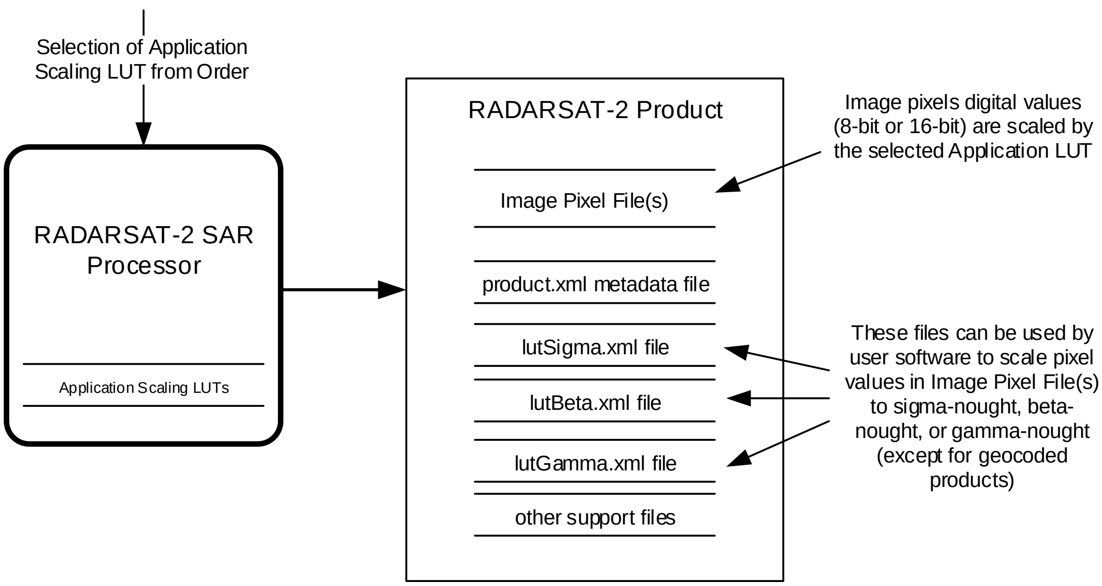

Figure 1-1 Application Lookup Tables in RADARSAT-2 Products

Note also that each RADARSAT-2 georeferenced (i.e. non-geocoded) product contains lutBeta.xml, lutSigma.xml and lutGamma.xml files that allow the user to directly scale the integer pixel values back to beta0, sigma0 and gamma0 backscatter. The scaling procedure is described in the RADARSAT-2 Product Format Definition Document (RN-RP-51-2713).

This note discusses the LUTs applicable to products with 16-bit or 8-bit pixel values, with emphasis on the 16-bit products. The 8-bit products are offered primarily for historical compatibility purposes and are not recommended for new users or for applications that are sensitive to radiometric distortion.

2 APPLICATION LUTS SELECTION GUIDE

The general recommendation is to use a brighter Application LUT if bright targets of interest are saturating, or a darker LUT if dark targets of interest are too coarsely quantized.

Table 2-1 gives more specific recommendations for 16-bit products, by RADARSAT-2 Beam Mode Type. Further details on the LUTs are provided below and in the next section.

Table 2-1 Application LUT Selection Guide for 16-bit Products

Beam Mode Type	Recommended LUT Default	Notes
Ocean Surveillance ScanSAR Wide ScanSAR Narrow	Constant-Beta	Use Sea, Ice or Mixed if flattening of the image levels over a wide range of angles is required, and saturation of bright features is not a concern. Use Constant-Gamma if flattening over land areas is desired.
Ship Detection (Detection of Vessels)	Ship-3	
Standard Wide	Constant-Beta	Use Constant-Gamma if flattening over land areas is desired. Use Ship-3 for ships.
Extended Low	Constant-Beta	
Extended High	Constant-Beta	
Fine Wide Fine	Constant-Beta	Use Constant-Gamma if flattening over land areas is desired. Use Point Target LUT if the scene contains urban areas, ships, or other very bright features.
Multi-Look Fine Wide Multi-Look Fine Extra-Fine	Constant-Beta	
Standard Quad-Pol Wide Standard Quad-Pol Fine Quad-Pol Wide Fine Quad-Pol	Constant-Beta	
Ultra-Fine Wide Ultra-Fine	Point Target	Use Calibration-1 or 2 if saturation of very bright targets becomes a problem.
Spotlight	Point Target	

Table 2-2 gives the list of LUTs and their recommended usage for 16-bit processing. Note that this table does not apply to 8-bit processing, which is not recommended.

Table 2-2 Application LUT Quick Reference for 16-bit Products

LUT	Recommended Usage	Notes
Constant-Beta	To produce an image file with pixel values proportional to beta-zero.	These three options are good defaults suited to general applications when flattening of the image levels over a wide range of angles is not required. Bright targets that are above 25 dB will be saturated in detected products; targets above 19 dB may be saturated in SLC (complex) products.
Constant-Sigma	To produce an image file with pixel values proportional to sigma-zero.	
Constant-Gamma	To produce an image file with pixel values proportional to gamma.	
Point Target	Imaging of urban areas or areas with potentially bright features. Recommended default for Ultra-Fine and Spotlight modes due to their high compression gains, which pose a higher risk of bright target saturation.	Flat (angle-independent) gain designed to avoid saturation for bright point targets. May provide coarse quantization of levels over areas of very low backscatter.
Point Target-1	Imaging of extremely bright features. Not recommended except in very special cases.	Flat (angle-independent) gain designed to avoid saturation of all types of targets. Coarsely quantizes all but bright targets.
Calibration-1	Analyzing signatures from bright calibration point targets.	Flat (angle-independent) gain designed for bright calibration point target analysis. Provides coarse quantization over areas of low backscatter.
Calibration-2	Analyzing signatures from very bright calibration point targets.	Flat (angle-independent) gain designed for very bright calibration point target analysis. Provides coarse quantization over areas of low to moderate backscatter.
Sea	Wider swath imaging of oceans when a display is required with more uniform levels across a range of incidence angles.	Intended to flatten the typical ocean backscatter variation with incidence angle. Land areas and ships may show saturation with this LUT, particularly at higher incidence angles.
Land	Wider swath imaging of land when a display is required with more uniform levels across a range of incidence angles.	Intended to flatten the typical land backscatter variation with incidence angle. Saturation may occur in urban areas or areas of high relief.
Mixed	Wider swath imaging of general land and water scenes when a display is required with more uniform levels across a range of incidence angles.	Same range variation as the land LUT but with less saturation for brighter features. NOTE: Not recommended for scenes including urban areas.
Ice	Wider swath imaging of areas of new and multi-year ice fields when a display is required with more uniform levels across a range of incidence angles.	Intended to flatten the typical ice backscatter variation with incidence angle. Brighter features, particularly in land areas, may show saturation with this LUT.

LUT	Recommended Usage	Notes
Ice-2	Imaging of ice in cross-polarized channels.	Intended to flatten the typical ice backscatter variation with incidence angle in cross-polarized channels.
Ship-1	Ship detection	This LUT is a 3 dB darker version of the Constant-Beta LUT, so quantization errors are higher but the risk of saturation is lower.
Ship-2	Ship detection	This LUT is similar to the Ship-1 LUT, except 3 dB darker, so quantization errors are higher but the risk of saturation is lower.
Ship-3	Ship detection	This LUT is similar to the Ship-2 LUT, except 3 dB darker, so quantization errors are higher but the risk of saturation is lower.

It should be noted that cross polarized backscatter is generally lower than co-polarized backscatter. Hence, the Point Target and Calibration LUTs are less likely to be required when processing cross-polarized products.

3 APPLICATION LUTS DETAILS

This section describes how the Application LUTs work and gives the characteristics of the available LUTs.

RADARSAT-2 detected products include scaled calibrated amplitude images in which pixel values (digital numbers (DNs)) are represented by 16-bit unsigned integers with DNs ranging from 0 to 65535, the exceptions being ScanSAR, SSG, and SPG products in which pixel values can optionally be represented by 8-bit unsigned integers with DNs ranging from 0 to 255, and SLC products in which in-phase (I) and quadrature (Q) values are represented as 16-bit signed integers. In terms of power, the 16-bit unsigned integer representation provides a dynamic range of 96.3 dBs while the 8-bit unsigned integer representation provides a dynamic range of 48.1dB.

The scaling of calibrated amplitude values into 16-bit or 8-bit integers is defined by an Application Look-Up Table (LUT). Several Application LUTs are available to suit different expected ranges of backscatter, some are constant with incidence angle while others vary with incidence angle. An Application LUT must be selected prior to processing each product.

At a particular incidence angle, the Application LUT defines the minimum non-zero beta0 backscatter represented by the product (DN = 1). The maximum beta0 backscatter represented by the product (DN = 65535 for a 16-bit unsigned integer representation, DN = 255 for an 8-bit unsigned integer representation) is then 96.3 dBs (for 16-bit) or 48.1 dB (for 8-bit) greater than the minimum.

While the dynamic range is 96.3 dBs for a 16-bit unsigned integer representation it should be noted that quantization is coarse over the lower part of the range. DNs 1 to 10 span the first 20 dBs and only the top 57 dBs of the range provide a resolution of 0.1 dB or smaller. This is illustrated in Figure 3-1 for a linear scaling.

Generally, the coarser quantization of individual pixel levels for areas of low backscatter does not adversely affect users because the only measurement of levels that are likely to be made over those areas is the mean level, in which the quantization effect is averaged out. However, this factor should be taken into consideration when selecting the LUT to be used for products for a specific application.

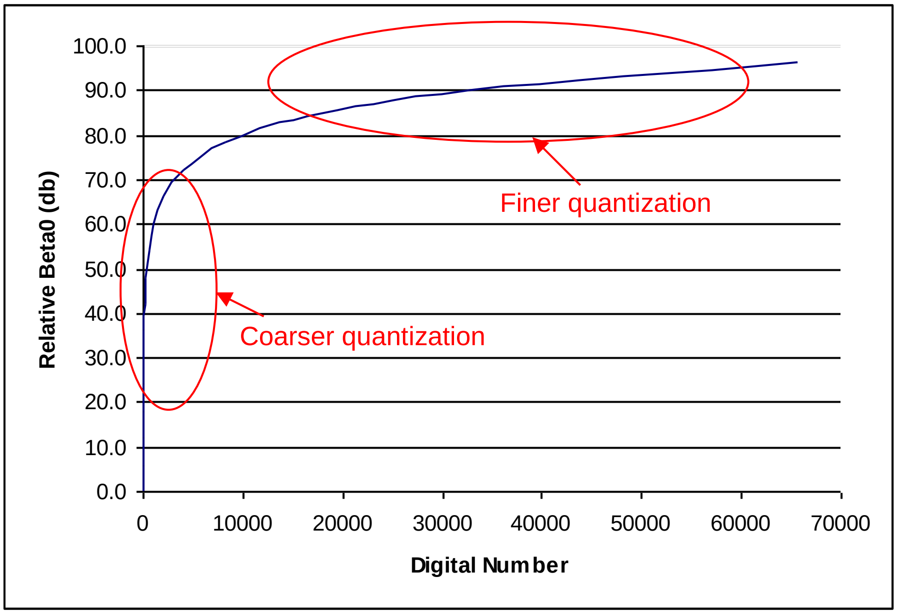

Figure 3-1 Relative Backstatter Values Represented as Digital Numbers for a Linear Scaling

3.1 Detected Georeferenced Products

This sub-section applies to detected georeferenced products (that is, products of types SGF, SGX, SCN, SCW, SCS, and SCF). Single-look complex (SLC) and geocoded (SSG, SPG) products will be discussed in later sub-sections.

The currently available Application LUTs are depicted for unsigned integer image data types in Figure 3-2 (16-bit) and Figure 3-3 (8-bit). The maximum and minimum non-zero Beta-nought values that can be handled by each of the LUTs are shown in Figure 3-4 and Figure 3-6 (16-bit) and in Figure 3-5 and Figure 3-7 (8-bit).

The Constant-Beta LUT (-71.3 dB to + 25 dB beta0 for the unsigned 16-bit case) is the default LUT suited to general applications. Bright targets above 25 dB will be saturated in the 16-bit unsigned product.

The Point Target LUT (-46.3 to 50 dB beta0 for the 16-bit case) is suited to applications involving scattering from bright point targets. This LUT is currently recommended for Spotlight and Ultrafine collects. It provides coarse quantization over areas of very low backscatter.

The Sea, Land, Mixed and Ice LUTs are suited to the thematic applications they describe, in which low backscatter features are expected. Bright targets will saturate. Values vary with incidence angle.

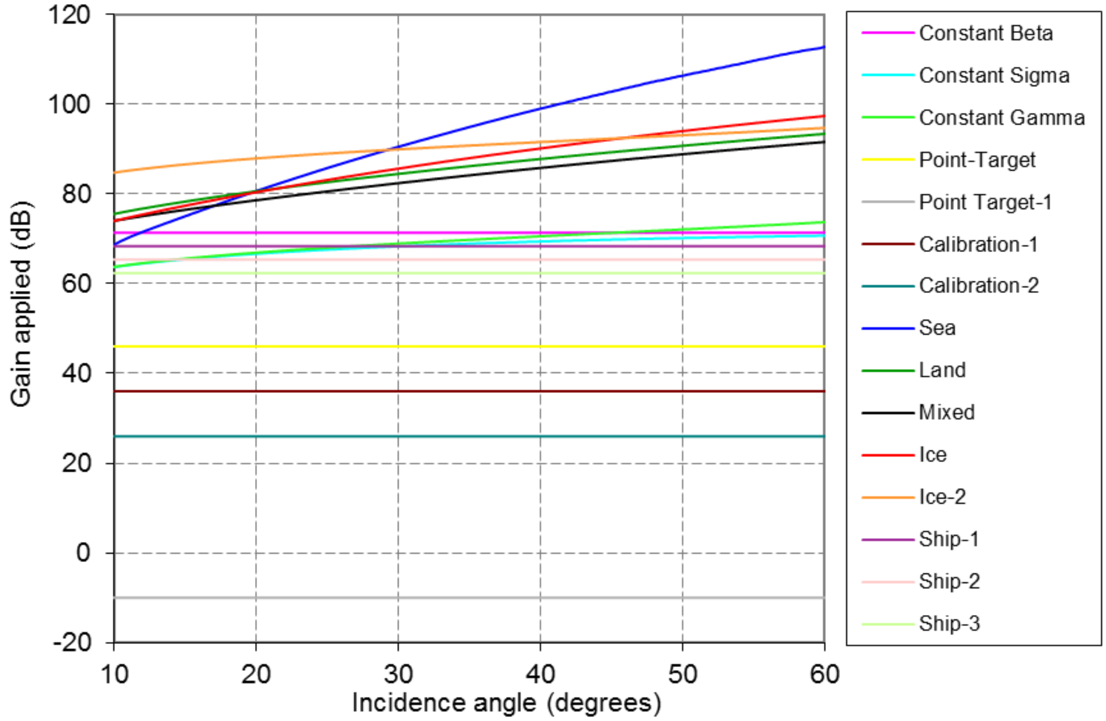

Figure 3-2 16-bit LUTs Gain vs. Incidence Angle

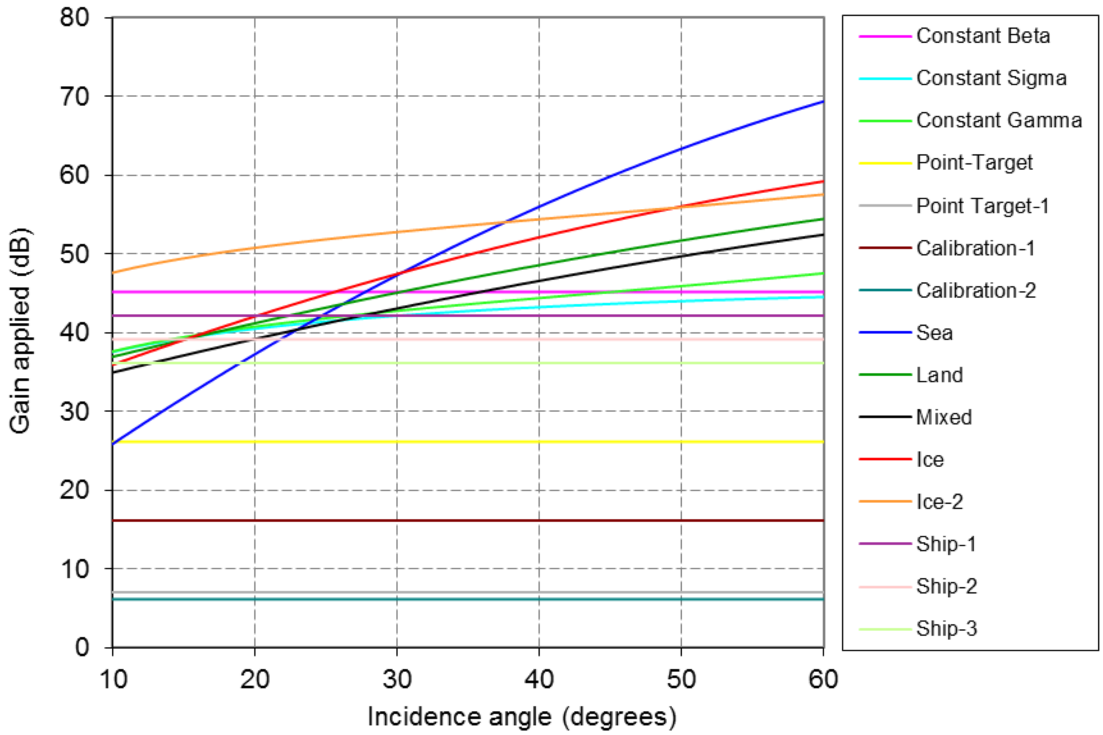

Figure 3-3 8-bit LUTs Gain vs. Incidence Angle

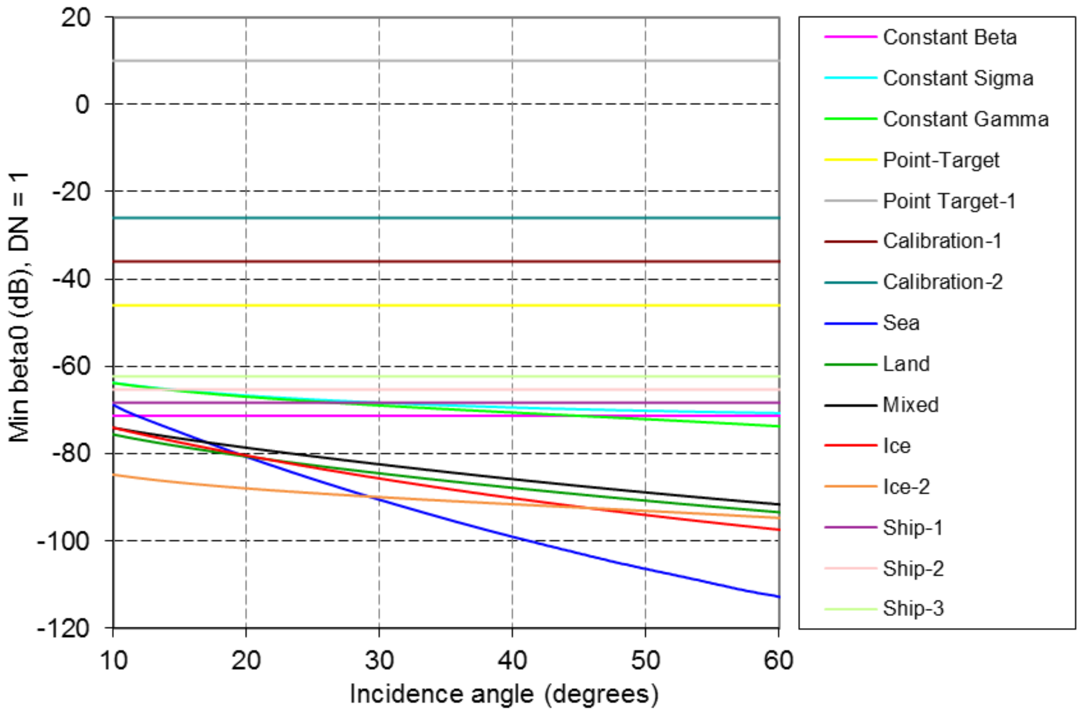

Figure 3-4 Minimum Non-Zero Beta0 Backscatter With Different 16-bit Application LUTs

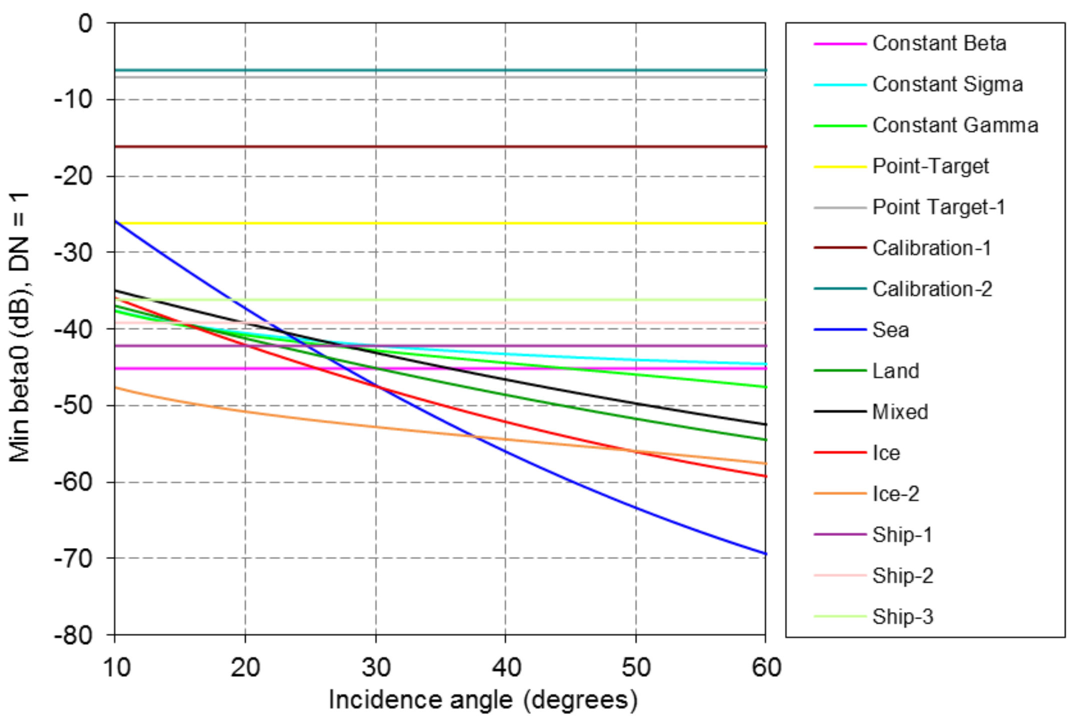

Figure 3-5 Minimum Non-Zero Beta0 Backscatter With Different 8-bit Application LUTs

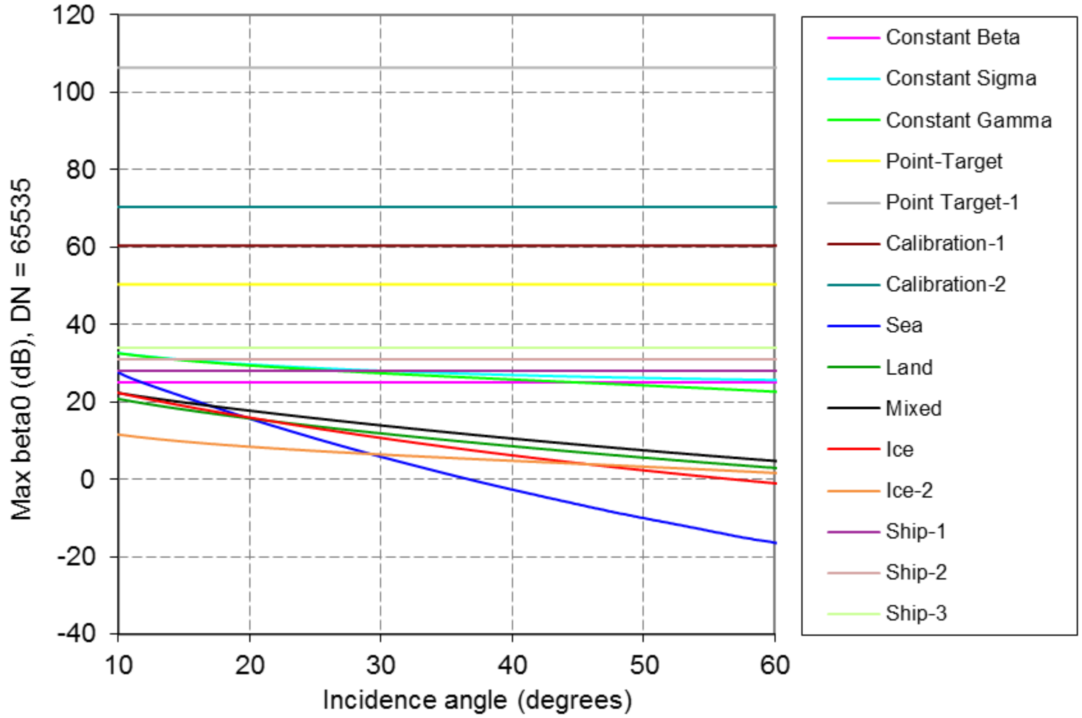

Figure 3-6 Maximum Beta0 Backscatter With Different 16-bit Application LUTs

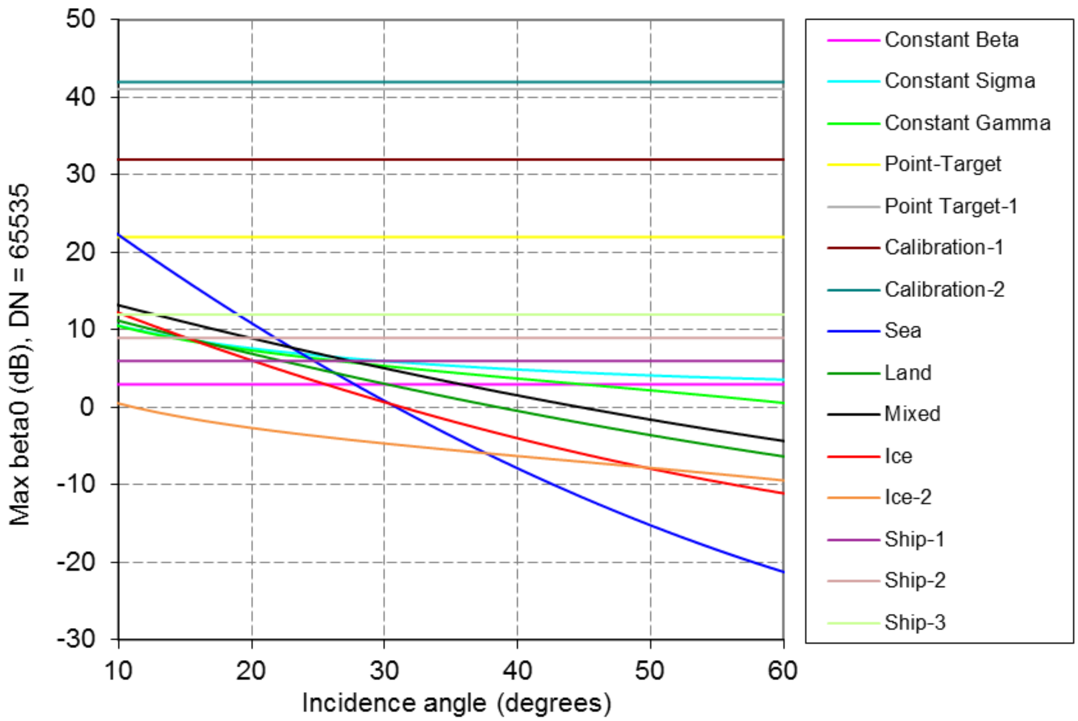

Figure 3-7 Maximum Beta0 Backscatter With Different 8-bit Application LUTs

3.2 Single-Look Complex Products

For SLC products the LUT gains are the same as for the 16-bit LUTs described above for detected georeferenced products in Figure 3-2.

However, since the image pixel values in the product are signed 16-bit integers (ranging from -32768 to +32767) for both the real part and the imaginary part of each complex sample (as opposed to unsigned integers ranging from 0 to 65535):

- The 16-bit minimum beta-nought values in Figure 3-4 above apply only to the power of the real or imaginary part individually
- The 16-bit maximum beta-nought values in Figure 3-6 above are 6 dB higher than the maximum beta0 corresponding to the power of the real or imaginary part individually

3.3 Geocoded Products

For 16-bit geocoded (SSG, SPG) products, the LUTs are the same as the 16-bit LUTs described above for detected georeferenced products.

For 8-bit geocoded products, the 8-bit LUTs described above for detected georeferenced products are not used. Instead, the 16-bit LUTs are used, and each image pixel is additionally scaled by -36.1 dB (divided by 64 in the amplitude domain) before being quantized to an 8-bit integer. So the effective LUT gains are 36.1 dB below those shown in Figure 3-2, and the minimum and maximum beta0 values are approximately 36.1 dB above those shown in Figure 3-4 and Figure 3-6.

It should be noted that in geocoded products the image pixels are lower-limited to a digital value of 1, instead of zero as in other product types. This is in order to differentiate them from blackfill pixels, which are set equal to zero.