AN ALTERNATIVE MULTI-MODE SAR FOR RADARSAT

R. K. Raney
RADARSAT Project Office
Ontario, Canada

I. INTRODUCTION

The RADARSAT project was asked by the Canadian government in the spring of 1986 to design for reduced costs and increased radar performance as compared to the well-known baseline design (Ref. 1). Both the Project Office and Canadian industry (lead by SPAR Aerospace of Montreal) have undertaken to meet this request, with a proposal to Cabinet to be submitted in the fall of 1986.

Innovation in partnerships, funding and business plans, and in SAR configuration will be required to achieve a programme with full government approval.

This paper outlines one alternative SAR concept which is under consideration for a revised RADARSAT configuration. The radar system described uses two frequencies (C&L band) over four possible modes: near range swath; far range swath; wide swath; and high resolution. Good sensitivity, resolution, and coverage are obtained with modest power and data rates. The antenna systems are relatively simple. Indeed, no break-through technological developments are needed. The design allows several mode combinations for simultaneous data collection or performance enhancement. The principal parameters are described in Table 1. A nominal mean altitude of 700 km is assumed.

II. SYSTEM HIGHLIGHTS

A two-frequency SAR system is proposed, having a high resolution mode and a wide swath mode. Like polarization is required, either HH or VV being acceptable. The frequencies suggested are C&L. Two nominal incidence angles of 21° and 49° are offered. These and related design features deserve some comment (Ref. 2). Derived specifications assume system losses of 5 dB, antenna losses of 4 dB (one way), and a noise figure of 2 dB.

A. Incidence Angles

From a careful review of the user requirements for incidence angle, it is clear that two incidence angle regions are needed, steep and shallow. Unfortunately, it is not possible to satisfy users by a single compromise with an intermediate angle, for such a choice leaves virtually everyone unsatisfied. Indeed, the users have gone on record as prefering two incidence angles as the dominant specification, with other parameters such as swath width to be sacrificed if need be (Ref. 3, Table 5). The current design attempts to be responsive to this requirement.

B. Frequency

The requirements favour C-band, with L-band desired as a parallel or back-up channel. The possibility of X-band, although appealing from the standpoint of air-borne data experience, does not seem feasible within the current state of the art. Recent work suggests that a frequency lower than L-band might be desirable, such as about 50 cm (in P band). The baseline alternative presented here is at C & L band. If two frequencies are available, they should be capable of simultaneous operation over the same swath coverage.

C. Wide Swath Mode

Wide swaths are more easily obtained at near range than at far range. Pressing swath width usually implies relatively more energy received from azimuth and/or range ambiguities. These two facts suggest that a wide swath mode be implemented at near range, and with somewhat relaxed range ambiguity restraints and sensitivity requirements.

Use of antenna rapid beam switching to synthesize wide swaths (Ref. 4) requires a comparable reduction in resolution. By use of one antenna pattern, and by accepting the possibility of larger range ambiguities, a rather wide swath can be achieved with no implied loss of resolution and with a rather simple antenna design.

D. Resolution

Most users have been influenced by positive experiences with SEASAT and the SIR series of radars. As a result, "everyone" wants about 25m x 25m x 4 look data. For many applications, however, a lower resolution (coupled with wide swath) is desirable. There is some demand for higher resolution data (with adequate looks), even though the swaths may have to be reduced to achieve it.

E. Image Quality

There is a uniform chorus of demand for image quality in a space SAR to be at least as good as that of SEASAT. This impacts all aspects of system design, including specifically sensitivity, resolution, and coverage. The example design described here attempts to respect reasonable allowances in this area. The system should incorporate calibration references and standards.

F. Mode Selection

Any pair of normal swath modes should be available, such as Near Swath (C) and Near Swath (L). To accommodate simultaneous (near and far swath) modes, the PRF should be chosen to be identical for both swath windows, and transmissions for L & C must be synchronized and simultaneous. Any two high resolution modes can be operated together, including two at the same frequency. Four high resolution channels are available using both C & L band, and using all four receivers, assuming conventional redundancy in SAR implementation.

III. HIGH RESOLUTION MODE

In order to achieve substantial improvement in resolution from a space radar constrained either by ambiguity considerations or data rate, some sacrifice in other performance parameters is mandatory. Swath width, system sensitivity, and along track image size are usually given up to achieve high resolution. A novel high resolution mode is proposed herein that minimizes both performance compromises and system complexity.

The logic of the design is approached as follows. High resolution may be achieved with an un-steered antenna using its full aperture if azimuth looks are exchanged for full azimuth resolution. Image quality can be maintained if looks are taken in range rather than in azimuth. High range resolution and range looks together normally imply very large range bandwidth, which if implemented in the usual way would result in a severe loss of SNR, and added restraints on the radar receiver, processor, and data handling.

In the conceptual design suggested here, a full range de-ramp scheme is used to realize the range resolution desired at relatively small cost in system bandwidths and complexity. This method (Ref. 5) depends on a very long linear FM pulse to be generated and transmitted, then used again as the demodulator reference against data from a range gated segment of the return signal. Only a relatively small bandwidth is required of the system after demodulation.

The results of a conceptual design analysis incorporating the deramp approach to high resolution are presented in Table 1. Since the design proposed is unusual, some aspects are elaborated here.

The full de-ramp approach requires additional performance of signal generation, transmission, demodulation, and timing control. For the design baselined here, a pulse 283 microseconds long of approximately 85 MHz bandwidth and linear FM rate of 0.3 MHz/microsec must be generated and transmitted. The same average power and PRF as in the normal modes can be used. On receive, a replica is used in demodulation leading to a required video bandwidth of 15 MHz, the same as that already built into the SAR for the conventional near range swath mode. Range gating of the received signal and timing of the demodulator replica to extract a narrow range swath from the far range window (approximately half of which is accessible in this mode) is done by an on-board computer. PRF is controlled as in the normal imaging mode. A continuous strip map is available 10 km wide with resolution better than 8m x 8m and 3 looks. The SNR is good, losing only 3.8 dB relative to the standard far swath image of this design. The bandwidth of the signal to be A/D converted and downlinked is 15 MHz, with a time duration of 233 microseconds. At 4 bits per sample for each of the in-phase and quadrature components, the average data rate is about 25 MBPS, including oversampling factors.

A second channel of high resolution data derived from the same transmission can also be received, digitized, and down-linked. This can be used to extend the effective high resolution swath width to 20 km, or to obtain simultaneous high resolution C & L band data. To receive two channels of one frequency simultaneously of course requires appropriate signal access in the receiver to those signals before the de-ramp demodulators.

If both the receive channels and the redundant receive channels are used, four reception paths are available. These can be used, two per wavelength, to bring the total high resolution swath width imaged to 40 km. The data rate (4 x 25 MBPS) is satisfactory. Adequate short-term storage registers must be provided after the A/D conversion to handle the required merge of four channels into one data stream.

The sensitivity of the radar to phase noise and platform motion increases with better resolution and with longer wavelengths. Likewise, processing complexity increases as wavelength/(resolution)^2. Finally, image content with respect to many user requirements is somewhat richer at C-band than at L-band. For these reasons, if only one channel of high resolution were implemented, C-band should be favoured over the longer wavelength. In the design proposed here, high resolution is available at small additional cost in both channels.

III. CONCLUSIONS

The baseline RADARSAT SAR uses eight (or more) beam positions for a single frequency (C-band) single resolution (30m x 30m x 4 look) 500 watt mean power system. The example conceptual design described in this brief note as an alternative is a two-beam position dual-frequency dual-resolution system with mean power of 360 watts. This radar as described is more responsive to many user requirements, and should be less expensive to realize in full spacecraft implementation. During 1986 RADARSAT will be restructuring its program using these and related ideas together with partnership arrangements to achieve a programme worthy of full government approval.

REFERENCES

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Table 1. Requirements on space SAR

	Near swath (C)	Near swath (L)	Far swath (C)	Far swath (L)	Wide (C)	Wide (L)	Hi res (C)	Hi res (L)
<u>Given specifications</u>								
AZ Resolution (m)	30	30	30	30	30	30	8	8
looks	4	4	4	4	4	4	1	1
R Resolution (m)	30 (21°)	30 (21°)	30 (49°)	30 (49°)	30 (21°)	30 21°)	8 (49°)	8 (49°)
looks	1	1	1	1	1	1	3	3
Swath width (km)	112	112	106	106	190	190	10(+10)	10(+10)
Incidence (near, far)	(17°, 26°)	(17°, 26°)	(46°, 51°)	(46°, 51°)	(16°, 31°)	(16°, 31°)	---	---
nominal	21°	21°	49°	49°	(26°)	(26°)	49°	49°
Noise Eq σ_0 (dB)	-26	-25	-28	-27	-20	-19	-24	-22
Azimuth ambiguities (dB)	< -22	< -22	< -22	< -22	< -22	< -22	< -22	< -22
Range ambiguities	< -30	< -30	< -20	< -20	< -18	< -18	< -24	< -24
<u>Derived specifications</u>								
Average power (W)	300	60	300	60	300	60	300	60
Average data (MB/S) rate (4I, 4Q)	48	48	48	48	96	96	25(+25)	25(+25)
Antenna length (m)	15	15	15	15	15	15	15	15
Bandwidth of RCVR (MHz)	15	15	7.5	7.5	15	15	15	15
Nominal PRF (Hz)	1300	1300	1300	1300	1300	1300	1300	1300