Volume 2, Issue 10, October 2012 ISSN: 2277 128X

International Journal of Advanced Research in Computer Science and Software Engineering

www.ijarcsse.com

Research Paper

Available online at: www.ijarcsse.com

A Shadow Enhancement in High Resolution SAR Images

Noorul Hassan
Research Scholar ,
CMJ University,
Mehalaya

Dr R. Mahammad Shafi
Professor and Head
Sree Vidyanikethan Engg. College
Tirupati

Abstract:- ***In synthetic aperture radar (SAR) images, the edge of the shadow is blurred because the radar is moving while the data are collected. In this letter, this problem is expanded on by using the imaging formation perspective. First, an approximate method to represent the imaging quality of the boundary of the shadow region based on the quadratic phase errors (QPEs) is provided for the first time, which built up the relationship between the parameters of the shadow caster and the behavior of the shadow in the SAR image. We notice that the QPE is approximately a linear function of the height of the caster. Second, we deduced the height-dependent phases due to the synthetic aperture process to the raw data, and a novel algorithm called height-variant phase compensation (HVPC) on the complex SAR image data is proposed by compensating the unexpected phases in the azimuth to sharpen the shadow. Compared with the traditional approach called fixed-focus shadow enhancement (FFSE), HVPC removes twice as much of the QPE as FFSE approximately. Experiments on simulation and real data demonstrate the precision and the better effect on shadow enhancement of our work. It is expected that the work in this letter could be some help for the SAR image understanding and application***

Keywords: Quadratic Phase Errors, SAR, FFSE

1. INTRODUCTION

This paper provides an overview of synthetic aperture imaging from its origins in radar and astronomy where it is known as synthetic aperture radar (SAR) and inverse SAR (ISAR) to its application to sonar where it is known as synthetic aperture sonar (SAS). The appropriate background reading is indicated and an historical review is made of the major steps in the development of the synthetic aperture technique and in its application to both the radar and sonar fields. The chapter concludes with the contributions and organization of this thesis.

1.3 Real Aperture Imaging

In real aperture imaging, a platform (eg., aircraft or towfish) containing a moderately large real aperture (antenna) travels along a rectilinear path in the along-track direction and periodically transmits a pulse at an angle that is perpendicular to the platform path[2]. This orientation of the radar or sonar system is termed side-looking, so these systems are typically referred to as *side-looking radars* (SLR) and side scan or *side-looking sonar's* (SLS). These systems produce *strip-map* images. A strip-map image is built-up as follows; the imaging system operates such that the echoes from the current pulse are received before the next pulse is transmitted. As these echoes are received, they are demodulated, pulse compressed, and detected (i.e., only the magnitude information is retained). Each detected pulse produces a *range line* of the real aperture image. As the platform moves, these range lines are displayed next to each other at pixel spacings that scale relative to the along-track spacing of the pulses, i.e., Δu = $vp\tau$rep, where vp is the platform velocity and τrep is the pulse repetition period. The final image is essentially a raster scan of a strip of the earth or sea floor, hence the name 'strip-map image'. Real aperture imaging is a *non-coherent* imaging technique, i.e., the *phase* of each echo is discarded; synthetic aperture imaging is a *coherent* imaging technique that exploits the extra information available in the phase of the real aperture data.

1.4 Synthetic Aperture Imaging

The coherent nature of synthetic aperture imaging means that focused images can be formed from platform data that has been collected over an almost arbitrary path. The two main modes of synthetic aperture imaging discussed in this thesis are *strip-map mode* and *spotlight mode*.[3]Other techniques such as inverse synthetic aperture radar (ISAR) and bistatic SAR are discussed in the references indicated in Section 1.5. Strip-map synthetic aperture systems operate in essentially the same manner as real aperture systems, except that the data received is stored or processed *coherently*.

Broadside operation describes the situation where the main lobe of the radiation pattern points at an angle that is perpendicular to the platform path. Non-perpendicular operation is termed *squint-mode*and is only briefly described within this thesis. To synthesize the effect of a large aperture, the received echoes from the imaged target field are coherently integrated (summed) in an appropriate manner to produce an image that has an along-track resolution that is *independent* of range and wavelength, a result contrary to that of real aperture imaging. In spotlight mode, the real aperture is continuously steered or slewed such that it always illuminates the same ground patch. The continuous illumination of the same scene allows an image to be produced that has an along-track resolution that exceeds that achievable from a strip-map system. However, this increased resolution comes at the expense of reduced area coverage. In military applications, the strip-map mode is typically used for mapping and reconnaissance, while the spotlight mode is used for weapon delivery and navigation system. As with real aperture imaging, the pulsed method of image generation leads to range and along-track ambiguity constraints.

The key feature of the synthetic aperture technique is using the information introduced in the along-track direction due to modulation of the received signal by the relative motion of the platform to the target. In the SAR literature this modulation is often referred to as the targets' *phase history*.

Many of the radar analyses of the phenomena refer to it misleadingly (as opposed to incorrectly).

Doppler modulation, then use what is known as the *stop-start* assumption to determine the relevant mathematics.

1.5 Synthetic Aperture Imaging

Have been received, that the platform instantaneously moves to the next along-track sampling location and the process is repeated. The stop-start assumption effectively removes movement from the system; therefore no *temporal* Doppler effect can exist. The correct term for the spectral content produced by the phase modulation in along-track is *spatial* Doppler, i.e., it is the rate of change of the relative platform-target distance that causes the *spatial* modulation of the return signal. The manipulation of the spatial bandwidth produced by this *geometrically* induced modulation is the essence of the synthetic aperture technique. True temporal Doppler effects cause a minor modulation within each transmitted pulse; however, for both radar and sonar this modulation can be ignored.

Given this brief overview of the (possibly) confusing aspects involved in analyzing synthetic aperture theory, the following mathematics parallel the usual (basic) SAR development of the synthetic aperture technique. Chapter 4 presents a more detailed development of spatial and temporal based strip-map and spotlight synthetic aperture systems.

The following mathematical arguments are similar to those that led the initial investigators of the strip-map synthetic aperture technique to use the method for high-resolution image production. The method for achieving high along-track (azimuth) resolution can be described as a focusing operation, a matched filtering or correlation operation, or an along-track compression operation. To determine the possible system resolution, it is necessary to investigate the system response to a point target. This investigation gives the spatially induced Doppler bandwidth produced by the relative platform-target modulation and indicates the basic form of the matched filter. The along-track system resolution can then be determined.

$$\phi(u) = -2\mathrm{ko} + (xo + \frac{u2}{2xo})$$

Due to the LFM nature of the along-track Doppler modulation, the along-track signal can be compressed using a LFM matched filter in a way that is similar to the pulse compression operation used to achieve high range resolution. This process is only *similar* because we have neglected to include the effect of the pulse envelope. In cases where the changing range to a target causes the envelope of the return signal to shift in range by more than (or a large fraction of) a range resolution cell, the along track matched filter becomes two-dimensional and more complex methods of along-track compression are required. This effect is typically referred to as *range migration* or *range curvature*. The presence of the delay term $2R/c$ in the delayed versions of the transmitted pulse in effects the modulation of the received echoes in realistic cases where the transmitted pulse itself contains some form of modulation.

2. Methodology

2.1 Signal Processing and Range Resolving Techniques

This introduces the relevant notation and signal processing concepts that are used within the scope of this thesis and within the SAR and SAS communities. This chapter begins with a brief review of sampling theory and its possible embodiments for synthetic aperture systems[6]. The utility of mapping operators is then discussed. Pulse compression techniques are reviewed and applied to one-dimensional imaging examples as a precursor to the two-dimensional imaging algorithms.

The waveforms commonly used by synthetic aperture systems and their properties are then presented along with their tolerance to temporal Doppler effects. The discussion on temporal Doppler encompasses a discussion on the ambiguity function and details its analysis for wide bandwidth applications. This analysis of the wideband ambiguity function shows that the 'stop-start' approximation commonly employed in radar to develop system models is also applicable to sonar. Finally, methods for the accurate interpolation of complex valued data are given.

The final image produced by a synthetic aperture processor should be calibrated such that pixel intensity reflects the scattering cross-section of the location being imaged. In SAR this is known as *radiometric calibration* and the scattering parameter is known as the *radar cross-section* (RCS), in sonar this scattering parameter is characterized by its *backscatter cross-section* or its *target strength*.

For accurate calibration, it is necessary to model the system completely, *including* the often neglected real or complex amplitude functions. This is especially important in wide bandwidth applications where these amplitude functions may *not* be constant. Calibration using these deterministic constants allows simulation errors or oversights to be quickly identified and easily corrected (these errors are missed if images are arbitrarily normalized to unity using the maximum image point). By including complex constants, comparisons of Fourier transforms calculated via the fast Fourier transform (FFT) can be made with their continuous or *analytic* forms.

2.2 Sampling Theory

The following arguments are developed for signals parameterized by time, t, and angular or radian frequency, ω. These arguments are equally applicable to signals parameterized in terms of spatial quantities such as distance, x, and wave number kx. Both temporal and spatial signals are analyses extensively throughout this thesis.

To digitally represent a continuous time domain signal $g(t)$ it is necessary to *sample* the signal. This (impulse) sampling operation is described by

$$gt(t) = g(t). \sum_{m=-\infty}^{m-\infty} \delta(t - m\nabla)$$

$$gt(t) = \sum_{m=-\infty}^{m-\infty} g(m\nabla t).\delta(t - m\nabla t)$$

Where Δt is the sampling interval and $gt(t)$ has a subscript 't' to indicate *temporal* sampling. It is important to note that (2.1) is still a *continuous* representation of the sampled signal. However, the sampled signal is fully characterized by the m samples given by $g(m\Delta t)$. The continuous nature of (2.1) is exploited in Chapter 5 when developing a model for, and explaining the effects of a long-track under sampling.

2.3 Real signals and Nyquist rate sampling

The signals used in synthetic aperture systems can be described in terms of *band-limited* functions. A band-limited real function, $gr(t)$, having an amplitude function $g0(t)$ and phase function $\varphi(t)$ at a carrier radian frequency $\omega 0$ is mathematically described by

$$gr(t) = go(t)\cos[\omega ot + \phi(t)]$$

The amplitude function $g0(t)$ is a slowly varying function also referred to as the envelope of the signal. In the range dimension of the synthetic aperture model, this amplitude function reflects the weighting of the transmitted pulse and in the along-track dimension it reflects the effect of the overall radiation pattern of the transmit and receive real apertures.

In the case of purely amplitude modulated (AM) pulses, the signal bandwidth is approximately given by the inverse of the temporal duration at the 3dB point of $g0(t)$. For the more usual case of some form of phase modulation (PM), the system bandwidth is determined by the the modulating phase. In either case, if the spectrum of the real signal is zero for radian frequencies $|\omega| \geq \omega$max, then temporal samples taken at spacings $\Delta t \leq \pi/\omega$max are sufficient to reconstruct the continuous signal (see Appendix A in Curlander and McDonough [31]). Sampling at the minimum allowable temporal spacing $\Delta t = \pi/\omega$max is termed Nyquist rate sampling. The *sampling frequency* $fs = 1/\Delta t$ or $\omega s = 2\pi/\Delta t$ represents the extent of the Fourier domain that is sampled by the system, and also represents the distance over which this sampled information repeats in the Fourier domain.

2.4 Mapping Operators

In many of the mathematical models described in this thesis, it is often necessary to use a change of variables. When dealing with continuous quantities this presents few difficulties, however, a digital implementation requires a sampled representation. If the change of variables is non-linear, then interpolation is often necessary to map the sampled data from one rectangular sampling grid to another. The sampling grid is required to be rectangular as much of the processing involves Fourier transforms via the FFT. Many of the mapping operators involve a simple axis scaling. Explicitly stating the change of variable through the use of a mapping operator improves the clarity of many of the synthetic aperture algorithms. Forward mapping operators are represented by bold symbols such as the Stolt mapping *S { • }* and the rotation operator *R{ • },* inverse mappings have the superscript '-1'. Fourier transforms are also mapping operations. Forward and inverse Fourier transformations are denoted by *F { • }* and *F*−1 *{ • }* and have subscripts denoting the domain *from* which the operation is being performed. The definition of the forward temporal Fourier transform.

3. EXPERIMENTS AND ANALYSIS

3.1 Waveforms Commonly Employed In Synthetic Aperture Systems Linear FM (chirp) waveforms

The linear frequency modulated (LFM) waveform is the most commonly used waveform in SAR and SAS processing. If a LFM pulse is produced at audio frequencies over a time period of say, one second, the resulting sound is a chirp, thus these waveforms are commonly referred to as chirp waveforms. Phase-coded waveforms[9]

Linear FM and hyperbolic FM belong to a wider class of waveforms known as phase modulated waveforms. The popular use of LFM and HFM in mapping or civilian applications is due in p art to the fact that they are relatively easy to produce. Phase modulation using binary phase codes is a technique generally employed by military radar systems in an attempt to lower their probability of detection. The flexibility of digital systems means that the use of coded pulses for mapping is also a viable option. In a digital application, these waveforms are easy to generate, and easy to process. The transmission of multiple orthogonal codes can also be used as a method for increasing the effective along-track sampling rate of a synthetic aperture system, however, this is at the expense of degraded image quality due to the effects of self clutter (see the discussion in Chapter 5). The binary phase modulation schemes commonly used in SAR applications include; Barker codes, pseudo-random noise sequences (PRN), maximal length sequences (m-sequences), Huffman codes, and polyphase codes.

3.2 Practical Waveform Considerations

Range sidelobe levels in the pulse compressed data are directly related to the amplitude of the compressed pulsed spectrum. If a *matched filter* (i.e., including any amplitude effects) is used for pulse compression, then the pulse compressed spectrum is also the *energy spectrum* of the transmitted pulse. To obtain low sidelobe levels it is usual to add a weighting function to either the transmitted waveform, or apply a weighting function in the matched filter (or a combination of both). The pulse compressed spectra throughout this thesis are obtained via *phase only* matched filtering, or alternatively via *deconvolution* of the echo spectrum. The transmitted pulse is always a LFM waveform with a uniform transmission level in the time domain. The spectra produced after filtering ideally have uniform levels. Hamming weighting is then applied to reduce the characteristic sinc sidelobes in the image domain down to an acceptable level of -43dB . See Chapter 7 of Cook and Bernfeld for a detailed discussion of window functions and their effects (and transforms) in the time (space) and frequency (wave number) domains.

LFM waveforms are typically transmitted *without* amplitude weighting, this is because it is preferable to operate the transmit power amplifiers at a constant level. The weighting function is then applied on reception, during pulse compression An additional method of reducing range side lobes is to transmit non-linear FM waveforms (NLFM). Using a waveform with LFM over the majority of the pulse with small portions of higher FM rate signal at the beginning and end of the pulse

Produces a pulse compressed waveform with extremely low side lobes.

In radar applications, an ideal broadband transmission channel is usually assumed. This assumption is not valid for wide bandwidth sonar. The band pass characteristic of most ultrasonic transducers limits the achievable pulse compression SNR gain of the sonar system. Because of this band pass characteristic, some sonar applications require techniques that determine the 'optimum bandwidth' appropriate for the transducer within the sonar system. When a transducer has wideband characteristics (i.e. has a constant amplitude, linear phase transfer function over the transmitted signal bandwidth) the pulse compression time-bandwidth gain is monotonic with increasing signal bandwidth. For the case of a band pass transducer, the time-bandwidth gain has a maximum. Increasing the system bandwidth past this maximum does not increase the pulse compression gain . Similarly, the transmitted waveform can be designed to achieve maximum power transmitted from the transducer. By a process of amplitude modulation and non-linear frequency modulation (AM-NLFM) the transmitted signal can drive the transducer to its peak power to produce a sound pressure waveform into the water with a desired power spectrum and maximum possible energy.

3.3 Temporal Doppler Effects—Ambiguity Functions

Temporal Doppler causes a distortion of the modulation function *within* the pulses employed by SAR and SAS systems. The *spatial Doppler* shifts exploited by the imaging algorithms occur due to Doppler effects *between* pulses. If the relative platform-target range rate can be considered to be constant *over the length of the pulse*, then the velocity tolerances of the pulse need to be considered. If, however, the range rate cannot be considered constant over the pulse length, then the acceleration tolerance of the pulse must also be investigated. Higher order platform-target range derivatives are usually not important in mapping applications.

The ambiguity surface or ambiguity function gives a measure of the correlator (matched filter) response to a return (echo) signal that is mismatched from the reference signal in delay and temporal Doppler, i.e., the ambiguity function indicates first order *range rate* effects.

If the transmitted waveform can be considered to be Doppler tolerant, then the receiver complexity drops as only one matched filter is required for pulse compression. The use of Doppler tolerant waveforms is useful in moving target identification and range velocity imaging. However, for the imaging.

3.4 Principles of Array Theory

The synthetic aperture principle can be presented from two equivalent points of view; the spatial domain formulation (array theory) or in spatial Fourier transform space (the spatial Doppler formulation). This chapter begins by developing a wide bandwidth formulation of aperture theory using Fourier array theory. This wide bandwidth formulation is then related to classical aperture theory. Real and synthetic array theory is presented and *beam forming* techniques such as array steering, focusing and de-focusing are covered. Some of the classical aspects of beam forming are interpreted in terms of the wide bandwidth theory and some of the misconceptions of synthetic aperture theory are resolved. In particular, the correct interpretation of the effects of null suppression is given[9] The effect of the aperture radiation patterns in synthetic aperture systems are often incorrectly modelled. Especially in wide bandwidth, low-Q, systems where the radiation patterns have often been considered too difficult to model. This chapter shows how the spatial-temporal response of wide bandwidth active imaging systems can easily be incorporated into imaging models and inversion schemes.

A transmitter (or receiver) that generates (or receives) with an equal response, independent of angle is known as an *omni-directional* element. An omni-directional element is (mathematically) considered to have an infinitesimally small physical extent. To construct an aperture (or antenna) with a response over a given solid angle in a given direction a number of these omni-directional elements can be spaced over a two-dimensional plane to produce a *real array*. If all of the elements in this real array are powered up (energized) simultaneously then the omni-directional response from each element interferes constructively and destructively in the medium in front of the array. Given a *simultaneous* excitation of all elements, the element patterns interfere *constructively* only over angles centered about the normal to the array face (the array *boresight*) and produce a main beam or main lobe over a solid angle that depends on the dimensions of the planar array and the frequency of the energizing signal. If the elements in the array are energized at different times, then it is possible to *steer* and *focus* the main lobe of the array to any given direction, this type of array is known as a *phased array*. The interference patterns of the energized elements with respect to angle from the bore sight of the array are known as *beam patterns*,

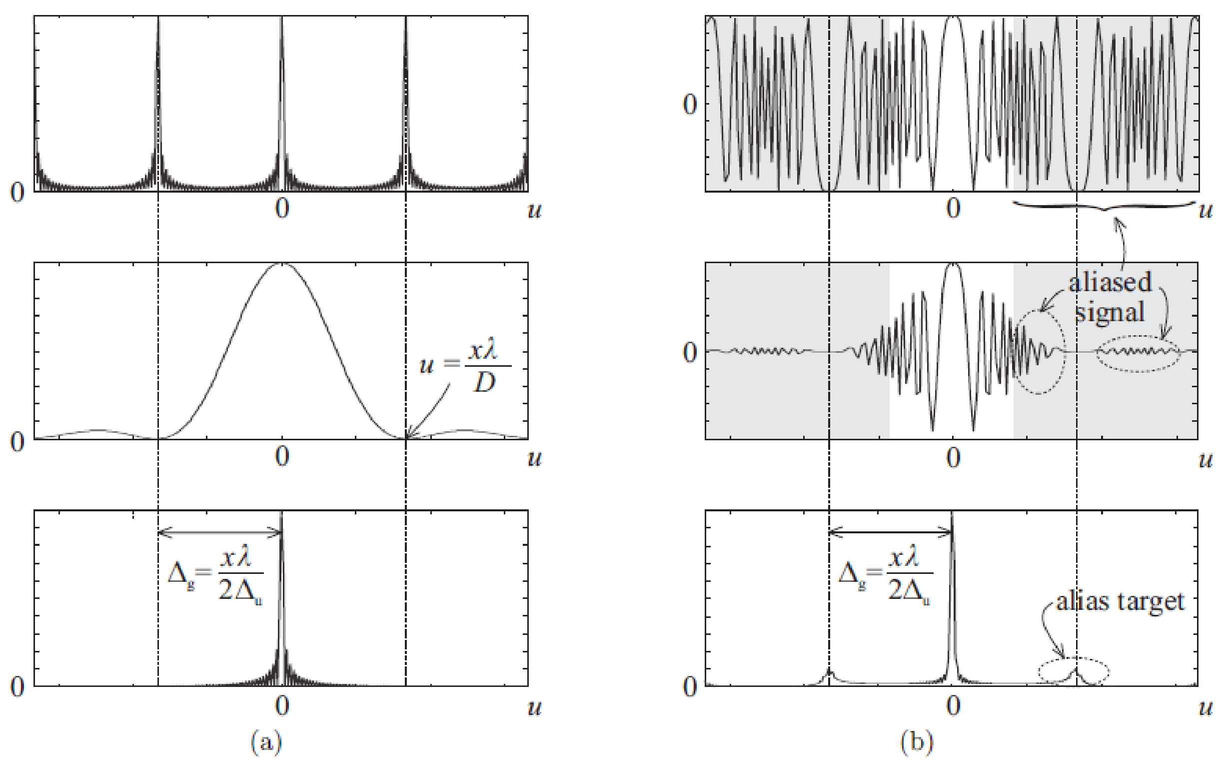

Fig: The effect of the real aperture radiation pattern on along-track under sampling, (a) classical grating lobe suppression interpretation, (b) correct interpretation. The aliased signal indicated in grey in (b) corresponds to along track locations where the PRF is not high enough to adequately sample the along-track phase (the repeated low frequency components away from $u = 0$ are where the along-track signal aliases to $k_u = 0$).

3.5 Synthetic Aperture Imaging Algorithms

Synthetic aperture imaging algorithms can be broadly classified into three groups; spatial-temporal domain processors , range-Doppler processors, and wave number processors. The mathematical notation used in synthetic aperture references to describe each system model is wide and varied. By applying multi-dimensional signal processing techniques, each of these synthetic aperture algorithms is described within a coherent and unified mathematical framework. The use of mapping operators to emphasize the coordinate transforms involved in each algorithm is an important step in clarifying their operation. By representing each system model in a consistent framework a comparison of ech algorithm can be made and the relationship between strip-map and spotlight modes can be determined[5]. It also allows a comparison of similar inversion schemes found in fields such as holography, computerized tomography (CT), magnetic resonance imaging (MRI), x-ray crystallography, radio astronomy, and seismics. Another objective of this chapter is to represent these algorithms to the accuracy required for direct digital implementation in realistic synthetic aperture processors.
This chapter begins by giving an overview of what a synthetic aperture system is trying to achieve. The *spatially-induced* strip-map synthetic aperture model and the various inversion algorithms are developed in what is effectively a *chronological* order. This order is; the spatial-temporal domain processor, the range-Doppler algorithm, the wave number algorithm, and the chirp scaling algorithm. This is followed by the spotlight synthetic aperture model and its inversion schemes. *Velocity-induced* FM-CW imaging inversion is presented and related to the spatially-induced model. Finally, slant-to-ground plane conversion, multilook processing, and the practical implementation of a parallel processing unit is discussed.

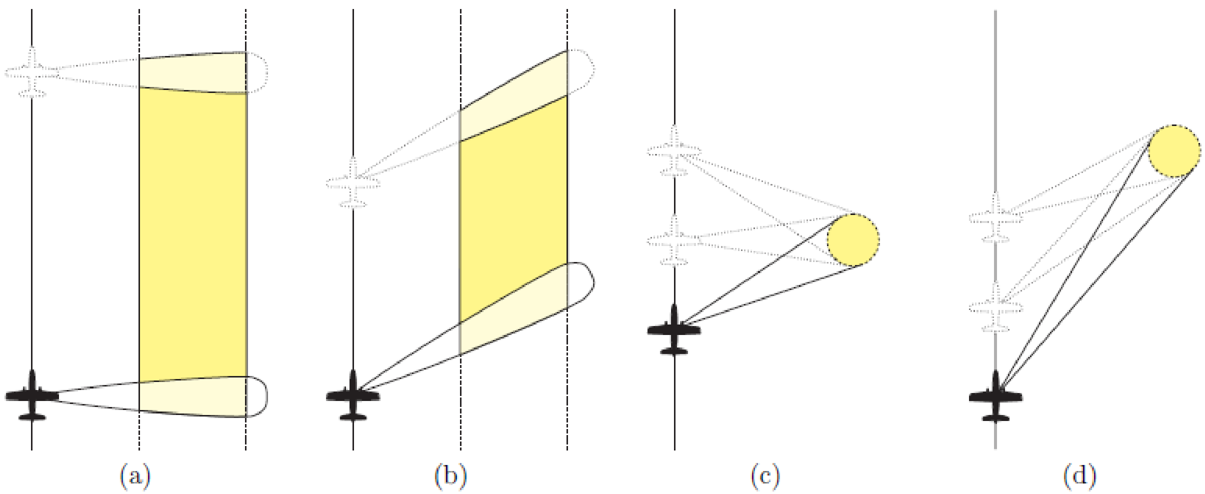

Figure3 Synthetic aperture imaging modes, (a) broadside strip-map, (b) squinted strip-map, (c) broadside spotlight, and (d) squinted spotlight. The light shading is the collected data; the dark shading is the valid data after processing.

4. CONCLUSION

In this paper we have shown how to exploit symmetric “flapping” modes in the head-piece of a Tonpilz transducer. Attempts to model this transducer using one dimensional models has shown the inability of these models to handle flexural modes other than by introducing assumptions of multi-piston resonance. Contrary to the one-dimensional model results, the Finite Element Method correctly predicts the performance characteristics of the transducer. The “flapping” mode of the transducer was exploited by lip-mounting the transducer in its housing, as opposed to the commonly used nodal mount. The lip-mounted transducer did not show any of the detrimental effects of previous designs. A comparison with a recent design shows that the multi-resonant design can produce a transducer with characteristics that exceed more conventional one dimensional design methods. The final Tonpilz design had a broad-bandwidth (low-Q), low-ripple, high-electroacoustic efficiency, high electromechanical coupling, and is able to be driven at high-power levels. These characteristics are rarely seen in previous Tonpilz designs.

REFERENCES

[1] A. E. Adams, O. R. Hinton, M. A. Lawlor, B. S. Sharif, and V. S. Riyait. A synthetic aperture sonar image processing system. IEE Acoustic Sensing and Imaging Conference, pages 109–113, March 1993.
[2] A. E. Adams, M. A. Lawlor, V. S. Riyait, O. R. Hinton, and B. S. Sharif. Real-time synthetic aperture sonar processing system. IEEE Proceedings on Radar, Sonar, and Navigation, 143(3):169–176, June 1996.
[3] AMP Incorporated, P.O. Box 799, Valley Forge, PA 19482. Piezoelectric copolymer hydrophone tile (hydrostatic mode), 1993. Application specification 114-1082 (01 FEB 94 Rev B).
[4] D.K. Anthony, C.F.N. Cowan, H.D. Griffiths, Z. Meng, T.A. Rafik, and H. Shafeeu. 3-D high resolution imaging using interferometric synthetic aperture sonar. Proceedings of the Institute of Acoustics, 17(8):11–20, December 1995.
[5] D.A. Ausherman, A. Kozma, J.L. Walker, H.M. Jones, and E.C. Poggio. Developments in radar imaging. IEEE Transactions on Aerospace and Electronic Systems, 20(4):363–399, July 1984.
[6] R. Bamler. A comparison of range-Doppler and wavenumber domain SAR focussing algorithms. IEEE Transactions on Geoscience and Remote Sensing, 30(4):706–713, July 1992.
[7] B. C. Barber. Theory of digital imaging from orbital synthetic aperture data. International Journal of Remote Sensing, 6(7):1009–1057, 1985.
[8] R. H. T. Bates, V. A. Smith, and R. D. Murch. Manageable multidimensional inverse scattering theory. Physics Reports, 201(4):187–277, April 1991.
[9] D. Blacknell, A. Freeman, S. Quegan, I. A. Ward, I. P. Finley, C. J. Oliver, R. G. White, and J. W. Wood. Geometric accuracy in airborne SAR images. IEEE Transactions on Aerospace and Electronic Systems, 25(2):241–258, March 1989.

Author :

Noorul Hassan, finished his B.E, Telecommunication engineering in Bangalore University in the year 2001, completed M.S- Digital signal and image processing in 2004. I am pursuing my PhD in CMJ university, Mehalaya My area of interest is Image processing,

