

YSAR and YINSAR: Compact, Low-Cost Synthetic Aperture Radars

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Abstract

Synthetic Aperture Radar (SAR) has proven useful for many different applications. Many more applications would be possible with a low-cost instrument. To address this need, BYU has developed YSAR and YINSAR. These compact, low-cost systems are operated from four or six passenger aircraft. The prototype system, YSAR, showed the feasibility of obtaining images with low-cost SAR. YINSAR is an interferometric SAR with many improvements over YSAR. This paper reports the current status of YSAR and YINSAR and presents the latest images from the YSAR data.

1 Introduction

In recent years, Synthetic Aperture Radar (SAR) images have been used in many different fields of study. One such field is archaeology. Several researchers [1, 2, 3] have used spaceborne SAR in a remote survey of the Taklamakan desert of China. They were able to see features such as waterways, ancient ruins, and sections of the Great Wall of China. Blom et al [4] and others have shown that SAR images can help in the detection of ancient roads. Another application is geology. Zebker and Rosen [5] used ERS-1 SAR data in differential interferometric mode to map the coseismic displacement fields resulting from a major earthquake, achieving sub-centimetric accuracy in displacement.

Many other applications of SAR are possible with appropriate instruments. For example, interferometric or differential interferometric SAR could be used to monitor the motion of a landslide by making periodic measurements. A mining company could use interferometric SAR to estimate the volume of material removed from a site. Power plants could use interferometric SAR to estimate the volume of coal reserves on hand. Detailed archaeological surveys of small areas can be performed to assist the archaeologists in making site maps and locating promising dig locations. Such applications require a SAR with low operating costs to give wide access

to the scientific community. A compact SAR which is mounted in a small airplane would be well suited for these applications and others.

To address the need for such a SAR, Brigham Young University has developed YSAR [6] and YINSAR. These are compact, inexpensive instruments designed to be flown in four or six passenger aircraft. The cost and complexity are kept low through the use of an all-digital IF and by using commercially available parts for most components. The original system, YSAR, was a prototype which showed the feasibility of small SAR. YINSAR is an interferometric system built on the experience gained from YSAR. Many aspects of the system have been improved. YSAR is now being rebuilt and integrated with the YINSAR system to benefit from these improvements and create a dual-frequency system. Some parameters of these systems are shown in Table 1.

This paper reports the current state of YSAR and YINSAR. Section 2 discusses the advances which have made our low-cost SAR possible. Sections 3 and 4 discuss YSAR and YINSAR respectively.

2 Low-Cost SAR

The keys in making the BYU SARs low-cost are the low operational cost and the low initial cost. The low operating cost comes by operating the instrument from a small plane. One of the significant design goals was to make the instrument small enough that it would take the space of one or two passenger seats. The instruments are designed to operate at low altitudes with low transmit power and small swath width.

The second major design goal was to make the instruments simple and inexpensive to build. The RF subsystems are simple, with an all-digital IF. Double sideband modulation increases the effective bandwidth while simplifying the RF system. An offset baseband allows real sampling instead of I and Q. The systems are still expected to achieve high resolution, as YSAR has proven.

A key reason that modest low-cost SAR systems

	YSAR	YINSAR	YSAR+YINSAR
Center Frequency	2.1GHz	9.9GHz	9.9 and 2.1GHz
Bandwidth	200MHz	200MHz	200MHz
Channels	1	2	3
Nominal PRF	400Hz	1kHz	1kHz
Maximum PRF	400Hz	6kHz	3kHz
Max Data Time at Nominal PRF	74 s	64+ s	43+ s
Swath width (pixels,m)	1024,600	1024,600	1024,600

Table 1: System Parameters

can be built is that the necessary analog and digital components are available at low cost. As technology improves, the performance of standard components increases while the price decreases. The performance of today's personal computers is such that they can support the data bandwidth required for these systems. High-speed analog-to-digital converters continue to become more widely available and boast higher data transfer rates to disk or memory.

The extensive GPS and differential GPS networks available today also help in implementing a full system with motion compensation at a relatively low cost. While these data are not accurate enough to eliminate costly inertial motion measurement units, they do aid in navigating and in reducing the long-term errors associated with inertial systems. Recent technological advances have also aided inertial measurement systems, by reducing the cost and by making the data easier to store and record. While nearly half of the cost of YINSAR is associated with the motion measurement subsystem, that cost would have been much greater only a few years ago.

3 YSAR

The success of the YSAR system [6] has shown that inexpensive SAR systems can produce useful images. The YSAR system was taken to Israel to collect data over archaeological sites in September 1996. The sites were in Zippori National Forest, Tel Safi, Tel Micnah, and Qumran. These images have revealed many features not evident from the ground and some not visible in aerial photographs.

Sample images from three of the sites are shown in Figs. 3-5. 64-look images are shown in order to fit an entire strip on the page. The flight direction is top to bottom, with the radar looking to the left of the page. Each strip is approximately 600m by 3.5km, with pixels about 2.5m by 2.5m.

The success of YSAR validates design decisions and tradeoffs made to minimize cost at the expense of some performance. No motion compensation system was included; however, the small airplane this

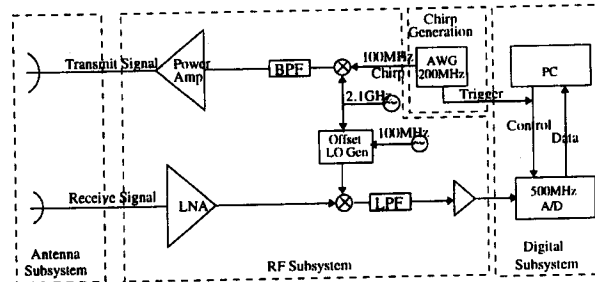


Figure 1: YSAR Block Diagram

system was mounted on had a large amount of undesirable motion, so some motion compensation is needed. We have recently been working on applying autofocus algorithms such as the Phase Gradient Autofocus (PGA) algorithm to optimize YSAR images. The YSAR block diagram is shown in Fig. 1.

4 YINSAR

YINSAR is an interferometric system based in part on the YSAR design. The block diagram is shown in Fig. 2. The custom RF subsystem was built with special care to improve robustness and signal-to-noise ratio. The motion measurement and compensation system combines differential GPS with high-accuracy inertial measurement. A micro-controller unit controls subsystem power supplies, thus reducing the load when not collecting data. The entire system is controlled through a graphical interface on a laptop computer. This interface includes a map to assist in navigation and to help guide the pilot onto the desired flight path.

The YINSAR instrument resides in three 17x19x7 inch (43x48x18 cm) rack-mountable boxes. These boxes respectively contain the computer, the RF/IF subsystem and system controller, and the motion measurement subsystem. The system consumes approximately 600 W in full-power operation. The transmitter is 10 W, with slotted-waveguide anten-

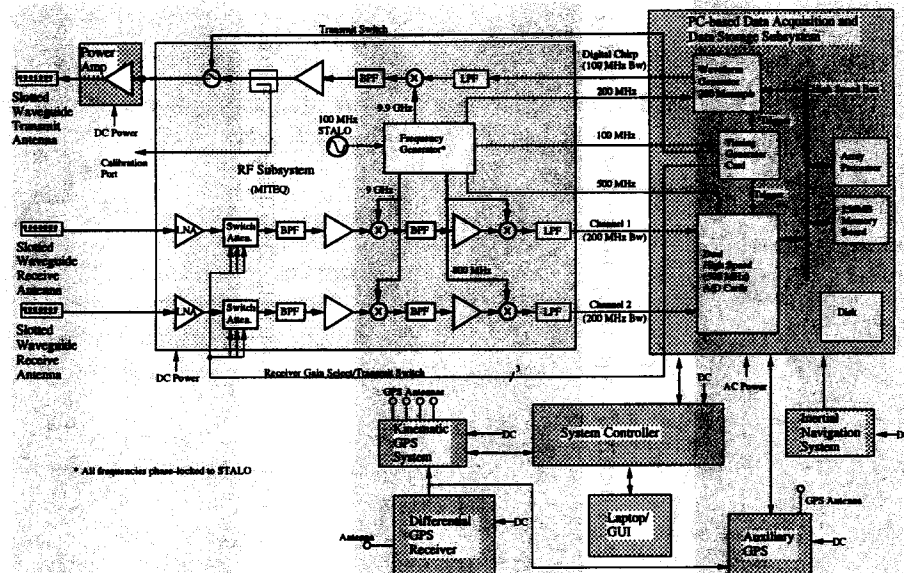


Figure 2: YINSAR Block Diagram

nas. An array of 10 slots forms the beam in the azimuth direction, and a small horn attached to the side of the waveguide forms the beam in the range direction. The beamwidths are 9 and 40 degrees in azimuth and range respectively. The interferometric baseline is approximately one meter and near horizontal.

The resolution of the interferometric images is expected to be better than a meter in all three directions. Range resolution will be on the order of a meter. Resolution in azimuth and in elevation should be a half meter or better. This system is currently in the final stages of ground testing. The YSAR rebuild is also proceeding as planned. These instruments are expected to be operated from an airplane soon.

5 Summary

In summary, there are many applications well-suited to low-cost SAR, including geological, archaeological, and commercial uses. That such systems can produce useful images has been demonstrated by the success of YSAR. YINSAR improves on the design of YSAR in many ways and is expected to produce images which are better and more useful.

6 Acknowledgements

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Figure 3. An image from the Tel Safi site. Two sets of corner reflectors are indicated.



Figure 4. An image from the Qumran site. An orchard, a road, and geological features are apparent in the image.

Look Direction ↓ Flight Direction →



Figure 5. An image showing the main Zippori site. A cross of corner reflectors is indicated in a field near the left edge.