# Design Considerations of GeoSAR

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ABSTRACT

The primary purpose of GeoSAR is to demonstrate the feasibility of interferometric topographic mapping through foliage penetration. GeoSAR should become a commercially viable instrument after the feasibility demonstration. To satisfy both requirements, we have designed a dual frequency (UHF- and X-band) interferometric radar. For foliage penetration, a lower frequency (UHF) radar is used. To obtain better height accuracy for low back scatter areas, we proposed a high frequency (X-band) interferometric system. in this paper, we present a possible GeoSAR system configuration anti associated performance estimation.

## 1. INTRODUCTION

High resolution digital topographic information is necessary for many applications such as seismic hazards mapping, land cover/use classification, and hydrology, Interferometric SAR (Synthetic Aperture Radar), introduced by Graham [1], anti Zebker and Goldstein [2], has demonstrated the possibility of providing fast topographic mapping of large areas. Unlike optical instruments, interferometric SAR is capable of mapping through foliage. However, when volume scattering is expected for imaged areas, the topographic height is not well defined since the true phase center is not easily identifiable. Even though evidence of foliage penetration using interferometric SAR has been shown using repeat pass interferometric data, true phase center locations may be obscured by other factors such as temporal decorrelation.

in order to image through foliage, operation at a lower frequency band is required. For GeoSAR, we use a 160 MHz bandwidth signal at 350 MHz center frequency. However, since the backscattering cross section of a flat area at UHF is low, tile height accuracy will be poor. These areas may not be phase unwrapped due to low correlation. Hence, we add an X-band interferometric SAR which will provide the desired height accuracy for most areas. The X-band data will help UHF interferometric calibration and it can also aid in phase unwrapping of the interferometric data. Currently, GeoSAR is in the middle of the system study phase and this paper summarize.s our preliminary results.

## 2._ GeoSAR INSTRUMENT DESCRIPTION

The GeoSAR radar is a dual-frequency (UHF and X-band) interferometric SAR with dual-polarization (HH and HV) capability at UHF. The proposed aircraft is a small business jet such as Learjet 35A or Gulfstream-II. This system can image an 11 or 22 km swath depending upon the choice of aircraft. For the Learjet which is more commercially viable, the system will have wing tip tank mounted UHF antennas, separated by 13 meters (26 meters baseline with the ping-pong scheme). For the Gulf-Stream II aircraft, the UHF antennas can be mounted underwing With a minimum Separation of 6 meters (12 meters baseline with the ping-pong scheme). Both aircrafts can support fuselage mounted X-band antennas. The Learjet will image a single 11 km swath while the Gulfstream-II aircraft can image both left and right sides of the aircraft. To measure the aircraft attitude accurately, GeoSAR uses a Honeywell H-764G GPS/INS and custom designed optical attitude determination systems.

The UHF antenna will be a sinuous (or broadband microstrip patch) type to support a bandwidth of 160 MHz with a center frequency of 350 MHz. The dimensions of this antenna are 63 cm (elevation) x 200 cm (azimuth). The peak transmit power is 4 KW derived from a solid state amplifier. The X-band antenna will be a waveguide fed microstrip antenna whose bandwidth is greater than 160 MHz. The X-band antenna will be 3.5 cm (elevation) x 150 cm (azimuth) in size. The X-band peak transmit power is 3.6 KW derived from a TWT (Traveling Wave Tube) amplifier.

The received signal will be coherently down-converted to a video signal and digitized by an ADC (Analog to Digital Converter). The digitized signal with proper headers will be recorded by a high rate tape recorder. The radar health will be monit ored constant 1 y over the data take period to inform any radar problems to the pilot. In addition, a flight correlator will provide low resolution SAR image to ensure that the correct area has been imaged.

## 3. PLATFORM

in order to be commerciall y viable, a small jet aircraft is chosen as the GeoSAR plat form. Two aircrafts are chosen as possible candidates. For lower operational cost, the Learjet 35A was considered. The other option considered is the Gulfstream I J. A comparison of two aircrafts are shown in '1'able ).

| | Learjet **35A** | Gulfstream II |
|---|---|---|
| Wing span | 13 m | 21 m |
| Crew & Passengers | 8 | 22 |
| Max Payload | > 3000 lb | > 8000 lb |
| Speed | 419 kts | 430 kts |
| Range | 1456 mi | 4275 mi |
| Operational Cost | ~ $ 900 /hour | ~ $ 1800 / hour |

Table 1. Learjet 35A and Gulfstream comparison for the GeoSAR application.

## 4. RADAR HARDWARE

in this section, we describe the intrinsic GeoSAR radar hardware which is rather insensitive to the choice of the platform.

### 4.1. Antenna Subsystem

The antenna size is determined by the illuminated ground swath size, left/right ambiguity, and azimuth ambiguity. In order to accomplish large area mapping, the ground swath is required to be larger than 10 km. Hence, we have set the swath size to 11 km for an altitude of 10 km. 'l'his translates to a look angle extending from 30 - 60 degrees. To avoid significant left/right ambiguity and multipath, the elevation beamwidth cannot be too broad. In the azimuth direction, the antenna length should be long enough to avoid Significant azimuth ambiguity for a given PRF (Pulse Repetition Frequency). The UHF antenna size is therefore 63 cm x 200 cm while the X-band antenna size is 3.5 cm x 150 cm.

The design of the UHF antenna is a challenging task due to the large bandwidth requirement. Currently, to obtain high resolution imagery, the chirp bandwidth is required to be 160 MHz. We selected the frequency range of 270 MHz -430 MHz. The UHF antenna types under consideration are broadband microstrip antennas (including stacked patch), annular ring, and sinuous antennas. The depth of the UHF antenna is smaller than 11 inches. in order to install the X-band antenna on the. fuselage, we have selected a microstrip antenna. However, since a coaxial cable suffers high 10SS, the feed structure will be a waveguide. The depth of the antenna is approximately 1 inch.

## 4.2. RFES Subsystem

in order to be commercially viable, GeoSAR device selection was mostly based on using commercially available catalog items. Coaxial components in rack-mounted chassis are used to assure the hardware is easily serviceable.

The UHF transmitter is required to provide 4 K W of peak power. The transmitter is composed of many broadband solid state. amplifiers. The X-band transmitter is a TWTA producing 3.6 KW of peak power. The chirp (linear FM) signal is generated by an NCO (Numerically Controlled Oscillator) based DCG (Digital Chirp Generator). The chirp signal is pre-amplified before it is fed into the UHF/X-band amplifiers. For the "ping-pong" mode of operation, the. signal is switched between two antennas.

The received signal from the antenna is diplexed in the circulator assembl y, and routed to the receiver where it is amplified and coherently downconverted to offset video. The circulator assembly consists of a three-stage circulator/ferrite switch assembly which provides sufficient isolation to protect the receiver from transmitter leakage and is also used to inject a portion of the transmit signal into the receiver to allow for built in test and calibration. The input of the receiver is further protected against overdrive from transmitter leakage by a limiter. An input filter, which eliminates out-of-band RFI and image noise, and low-noise amplifier precede the first downconverter. For the UHF receiver, a single-stage downconversion scheme is implemented, where. the input signal is translated to baseband which is again filtered, amplified and routed to the ADC. Digital step attenuators provide precision gain control to maximize system dynamic range. The X-Band receiver uses an additional stage to downconvert the X-Band input signal to an intermediate frequency. The intermediate frequency signal is then translated to baseband using an identical back-end as in the UHF receiver. This simplifies design, development and troubleshooting of the system.

The system can be periodicall y calibrated by coupling a mail amount of power from either the transmit pulse signal or an internal caliimtion-tone into the receiver by means of a calibration loop. Variations in transmit power and receiver gain can then be measured. The calibration loop attenuation is set such that the. calibration signal is just below receiver/ADC saturation. This assures that any leakage through the T/R switch is well below the calibration signal level to assure accurate signal measurements. The system also has the capability of measuring the system noise floor by making noise measurements during a receive only data take (transmitter disabled) or during a portion of the regular data take. In addit ion, a video test port is provided for self-t est, system calibration and fault isolation. The hard ware in the receiver allows for the various modes of calibration and self-test described. These modes are set-up anti control led by t he. radar control computer.

4.3. Digital Subsystem

The down-converted data is digitized by an 8-bit ADC. Five ADC's are required for all channels ( 3 UHF & 2 X-band). Then, using BFPQ (Block Floating Point Quantization) the 8 bit data is reduced to 4 bit data. The raw radar data is combined with the header information which contains radar parameters such as data window position, gain, and PRF. The platform attitude measurement data is combined with the radar data and recorded by a high rate data recorder.

It is important to make the GeoSAR operation autonomous in order to reduce operational cost. Using planning software, before the mission, radar parameters will be generated and used for radar control. This information is then used for both navigation and radar operation. To ensure correct operation, the radar health will be monitored during the mission and any abnormal state of the radar will be reported to the pilot and archived for later investigation. The data rates for GeoSAR are 172.8 Mbits/sec for UHF (3 channels = 2 interferometric + 1 cross polarization) and 115.2 Mbits/see for X-band (2 interferometric channels).

4.4. Attitude Determination Subsystem

For the fuselage mounted X-band system, the embedded GPS/INS system will be sufficient for attitude measurements. However, for the UHF antennas, the baseline vector measurement becomes more complicated due to wing motion. Here, the baseline vector is defined as a vector connecting from the phase center of one antenna to another. For the UHF system, we propose to use an optical metrological system which is composed on a laser based distance measurement device and two orthogonal 1-dimensional cylindrical lens/line array cameras. With this optical system, the relative baseline length will be measured better than 0.3 mm in a]] three directions. The metrology data acquisition rate is 100 Hz or higher. This body-coordinate baseline vector is transformed to inertial coordinates by combining with the. GPS/INS measurements. The expected baseline measurement accuracy is 0. 005 deg. (one sigma) in angle and 0.5 mm in length.

## 5. RADAR PERFORMANCE

The radar performance is summarized with related radar parameters as shown in Tables 2 and 3.

| Radar Parameter | Value |
|---|---|
| Posting | 5111 |
| Ground Swath | 11 km |
| Baseline Length | 26 m (ping-pong) |
| Baseline Tilt | o deg. |
| wavelength | 0.86 m (center frequency) |
| Antenna Look Angie | 30 - 60 deg. |
| Antenna Size | 2.0111 X 0.63111 |
| Polarization | HH and HV |
| Peak Transmit Power | 4 KW |
| Bandwidth | 160 MHz |
| Pulse Length | 20 μsec |
| PRF (Nominal) | 500 Hz (1000 Hz with ping-pong) |
| Duty Cycle (Nominal) | 2.0 % (ping-pong) |
| Sampling | 8 bit sampled 4 bit BFPQ (Block Floating Point Quantization) |
| Data Rate (per channel) | 172.8 Mbits/see |
| Height Accuracy | I-3 meters (relative)<br>3-5 meters (absolute) |

Table 2. Proposed UHF GeoSAR configurate ion and performance. The HH polarization is chosen to make usc of the ground-trunk interaction.

| Radar Parameter | Value |
|---|---|
| Posting | 5 m |
| Ground Swath | 11 km |
| Baseline Length | 2 m (ping-pong) |
| Baseline Tilt | 45 deg. |
| Wavelength | 0.03 m |
| Antenna Look Angle | 30 - 60 deg. |
| Antenna Size | 1.5 m x 0.035 m |
| Polarization | VV |
| Peak Transmit Power | 3.6 kW |
| Bandwidth | 160 MHz |
| Pulse Length | 20 μsec |
| PRF (Nominal) | 500 Hz (1000 Hz with ping-pong) |
| Dut y Cycle (Nominal) | 2.0 % (ping-pong) |
| Sampling | 8 bit sampled 4 bit BFPQ (Block Floating Point Quantization) |
| Data Rate (per channel) | 115.2 Mbits/sec. |
| Height Accuracy | 1-2 meters (relat ive)<br>2-3 meters (absolute) |

Table 3. Proposed X-band GeoSAR configuration and performance.

## 6. CONCLUSION

We have described a possible GeoSAR configuration and its associated performance. GeoSAR is a dual frequency (UHF and X-band) interferometric radar system. Currently, GeoSAR is in the middle of the system study phase. The final configuration may be different from the one presented in this paper. Using a dual frequency interferometric radar, we hope to acquire topographic and related data useful for military, government, and commercial users.

## 7. ACKNOWLEDGMENT

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## 8. REFERENCES

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