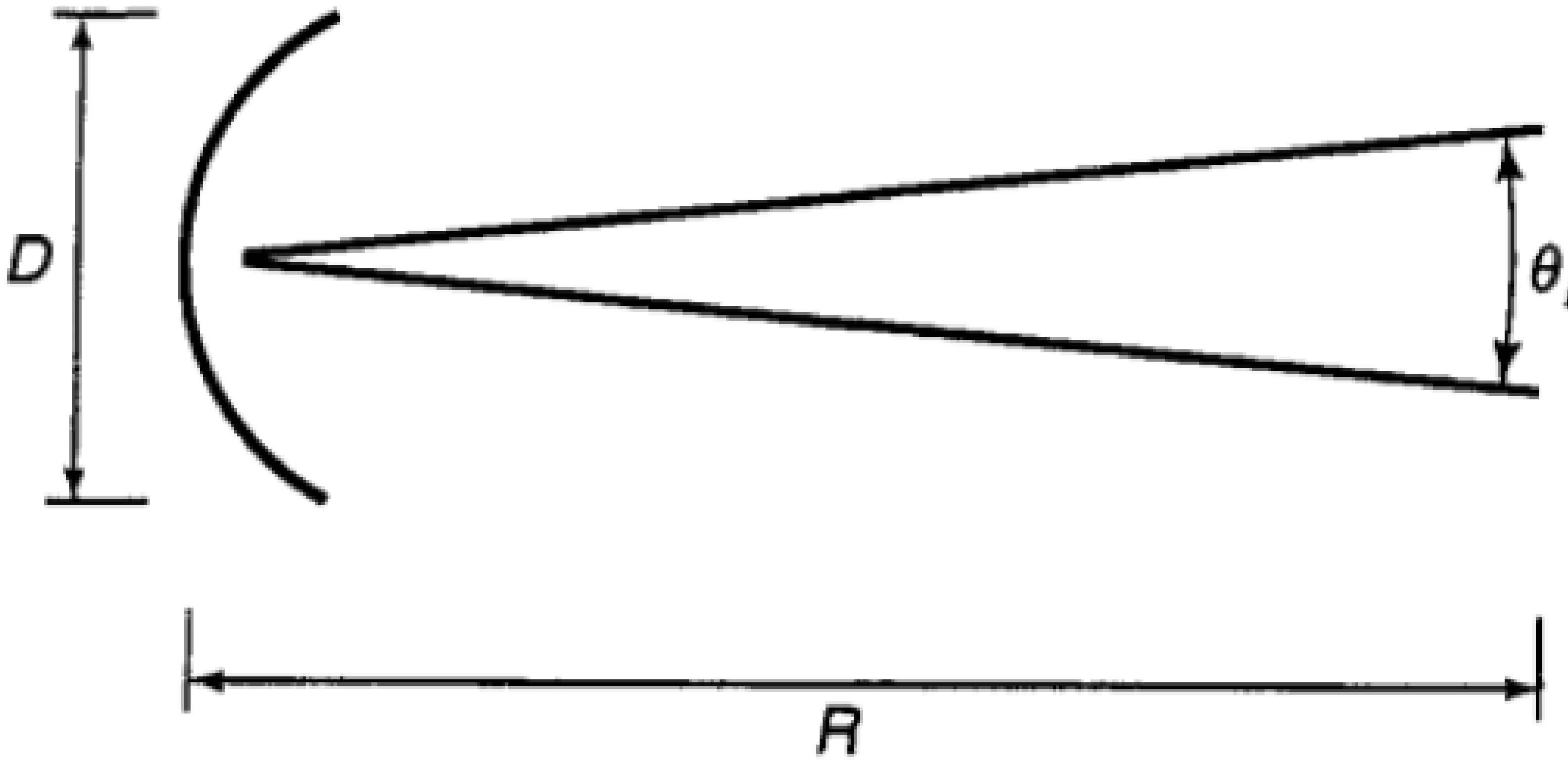
ADAVANCED RADAR SYSTEMS

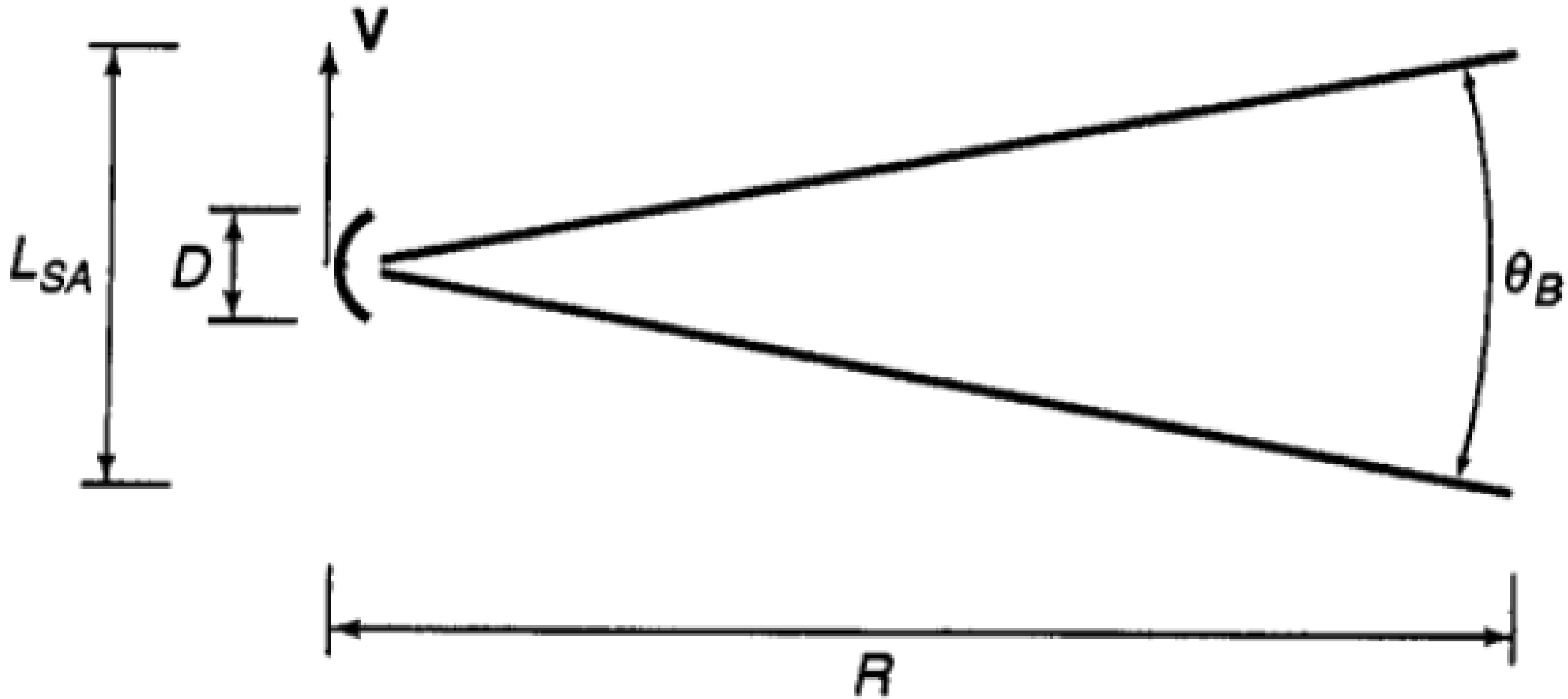
Introduction to SAR

- **Real Aperture Radar (RAR):** in which the antenna is a physical object that first emits, then collects the radiation.
- **Synthetic Aperture Radar (SAR):** case in which the antenna moves to cover a synthetic aperture *(L_{SA}).*
- **SAR generally refers to the case of a moving radar and a stationary target**-usually an extended scene, such as the surface of the Earth;
- **Inverse SAR (ISAR):** refers to the case in which the radar is relatively stationary and a rotating target provides all (or most) of the motion to create the synthetic aperture

RAR



SAR



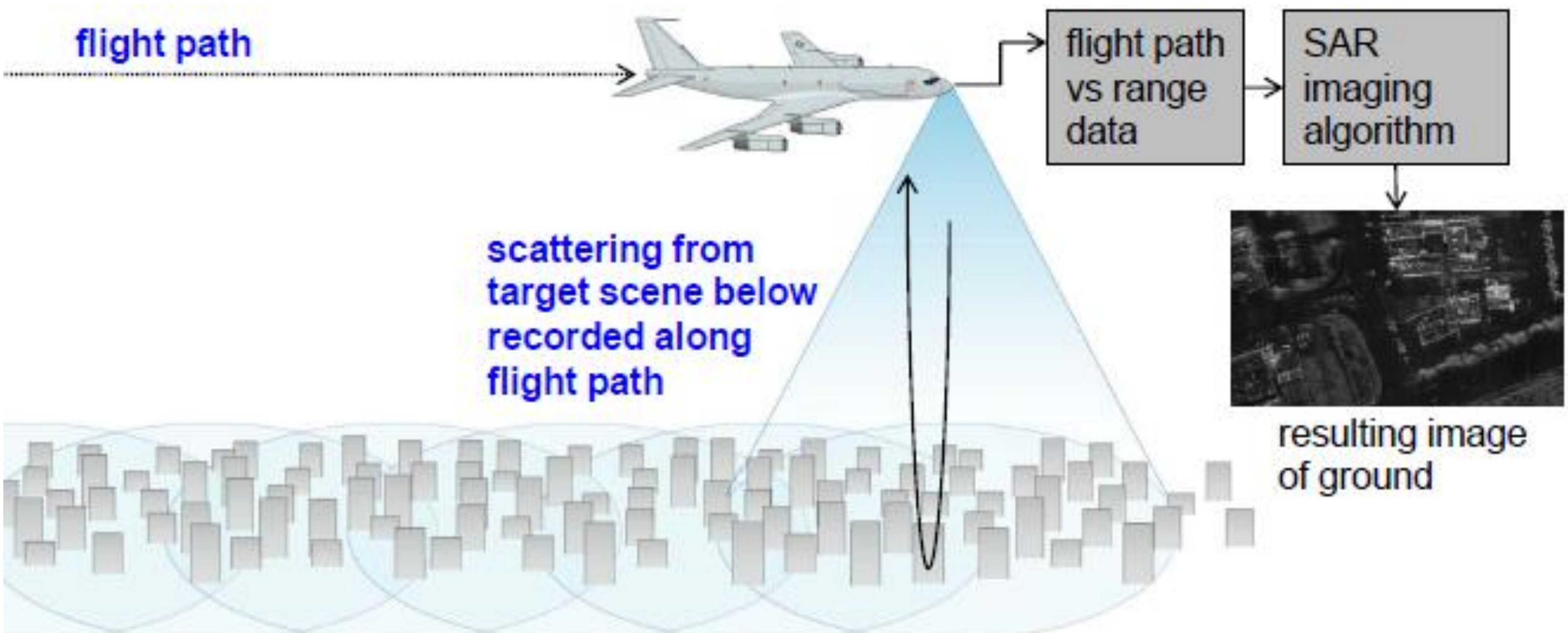
Problem with RAR

- In real aperture radar imaging, the ground resolution is limited by the size of the microwave beam sent out from the antenna.
- **Finer details on the ground can be resolved by using a narrower beam.**
- The **beam width is inversely proportional to the size of the antenna, i.e., the longer the antenna, the narrower the beam.**
- It is not feasible for a spacecraft to carry a very long antenna which is required for high resolution imaging of the earth surface.
- To overcome this limitation, SAR can be utilized.

Why SAR?

- **Fine Resolution** than the resolution for a RAR of equal aperture.
- For RAR the echo received at a particular aperture location results from energy transmitted from all locations in the aperture.
- For SAR, the echo received at a particular aperture location results from energy transmitted from known location in the aperture;
- **So, more information is received for SAR.**
- **Advantage of the long-range propagation characteristics of radar signals**
- **Complex information processing capability of modern digital electronics to provide high resolution imagery.**
- Imagery may be acquired **at night or during inclement weather.**

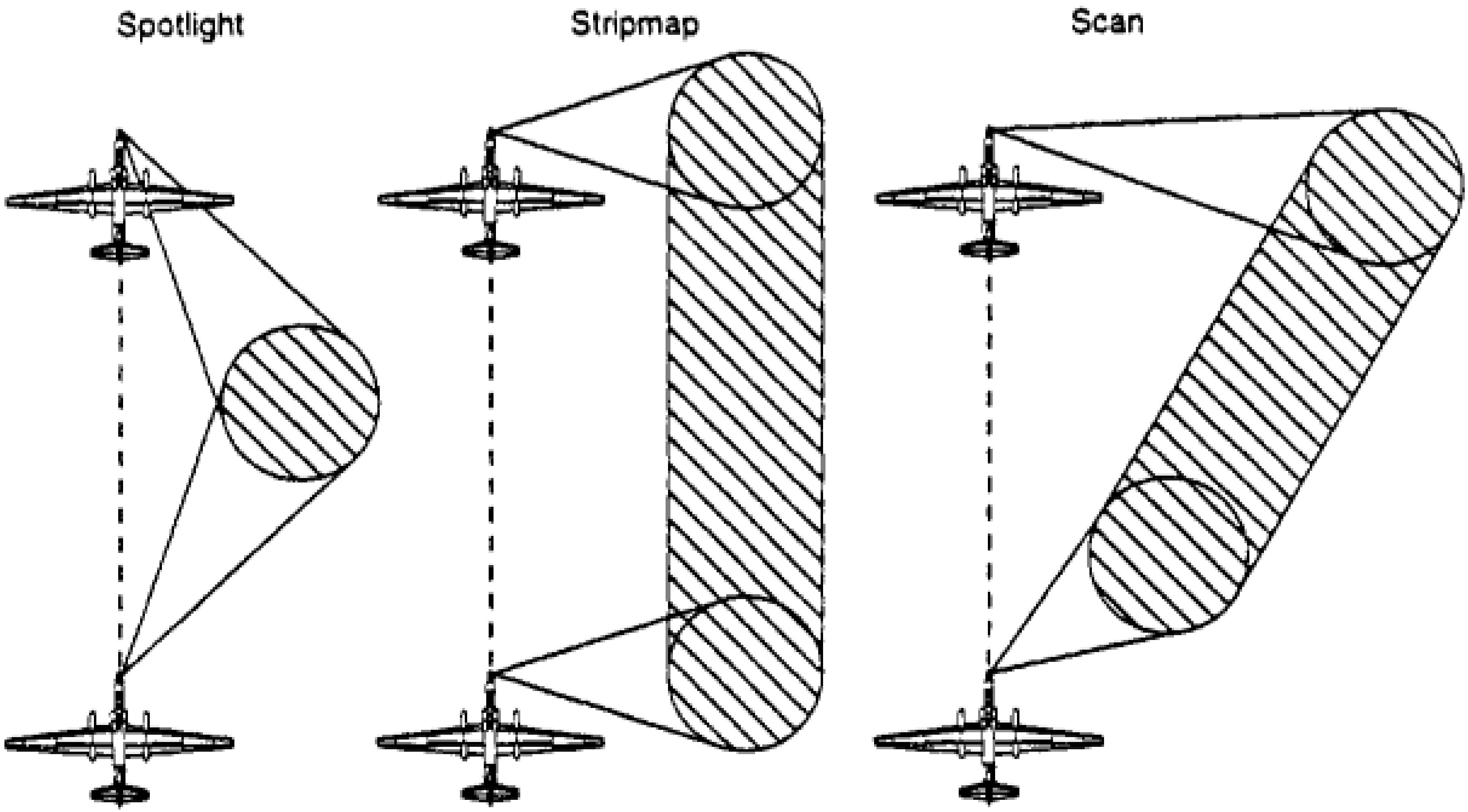
SAR Processing



Cross-range resolution of SAR

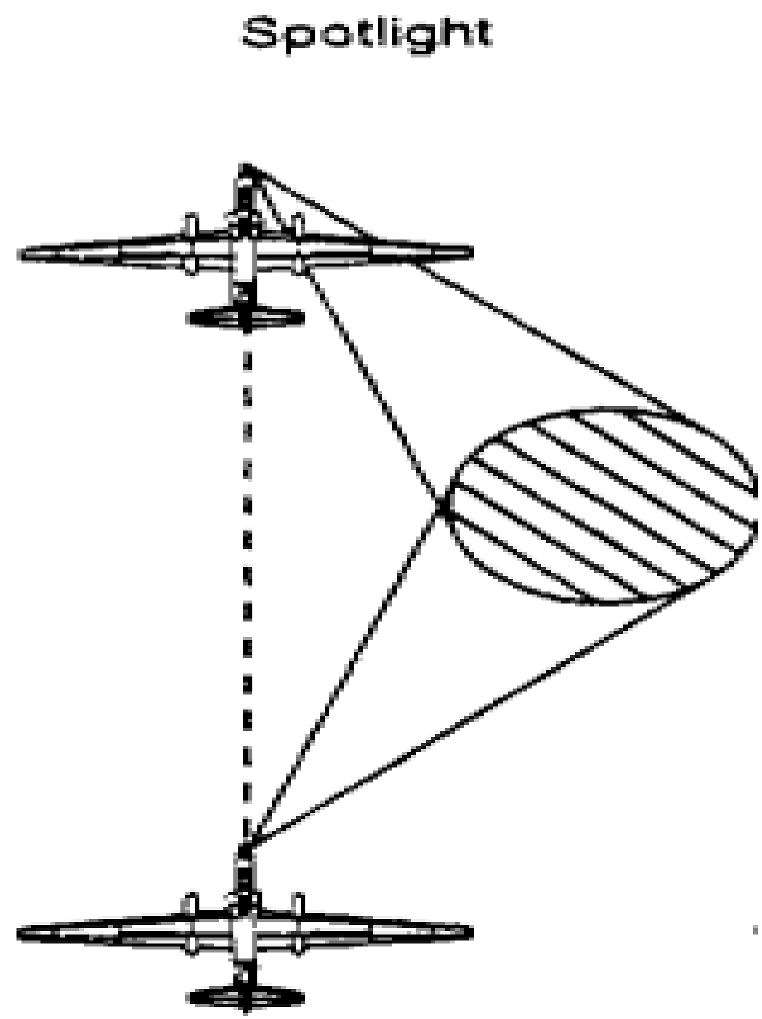
$$\delta_{cr}(SAR) \cong \frac{\lambda}{2\Delta\theta} \cong \frac{\lambda}{2(L_{SA}/R)} = \frac{R\lambda}{2L_{SA}}$$

SAR Modes



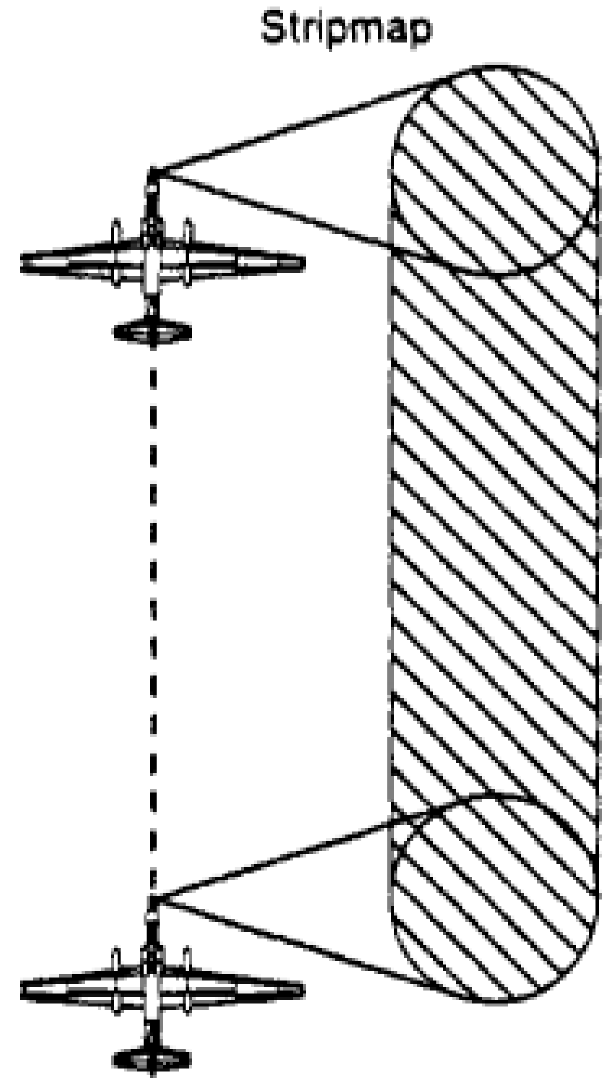
Spot SAR

- Spotlight SAR (or spot SAR), is used to obtain a relatively fine-resolution image of a known location or target of interest.
- As the platform passes by the target, the beam direction moves, to keep pointing at the target.



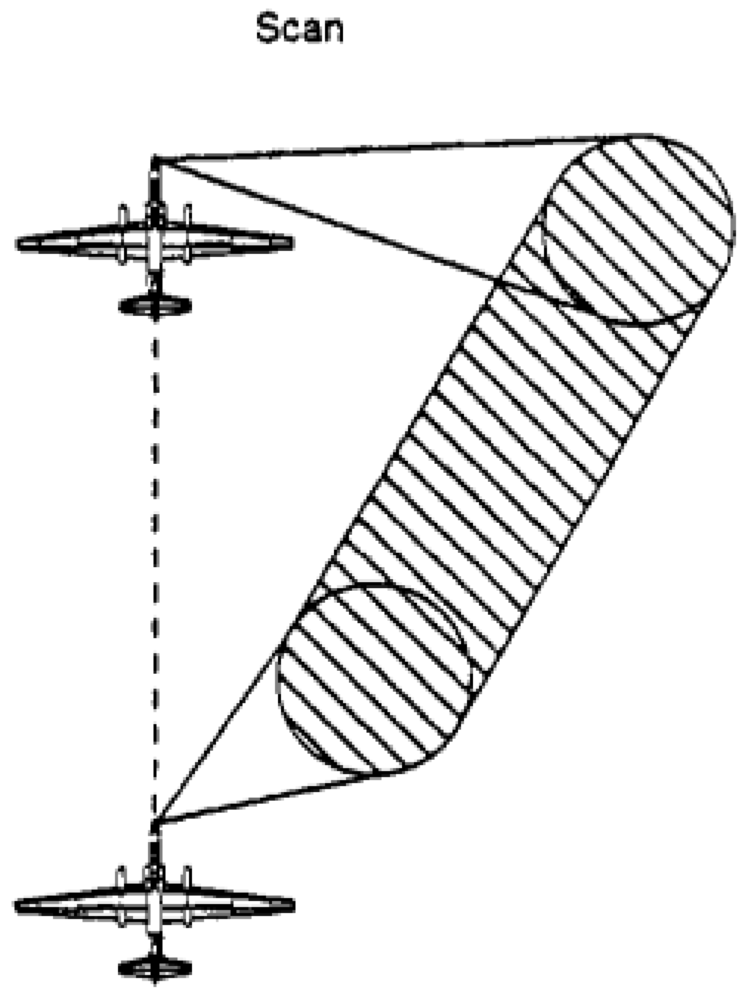
Strip-map SAR or Strip SAR or Search SAR

- Called as search SAR because it is useful for imaging large areas at relatively coarse resolution.

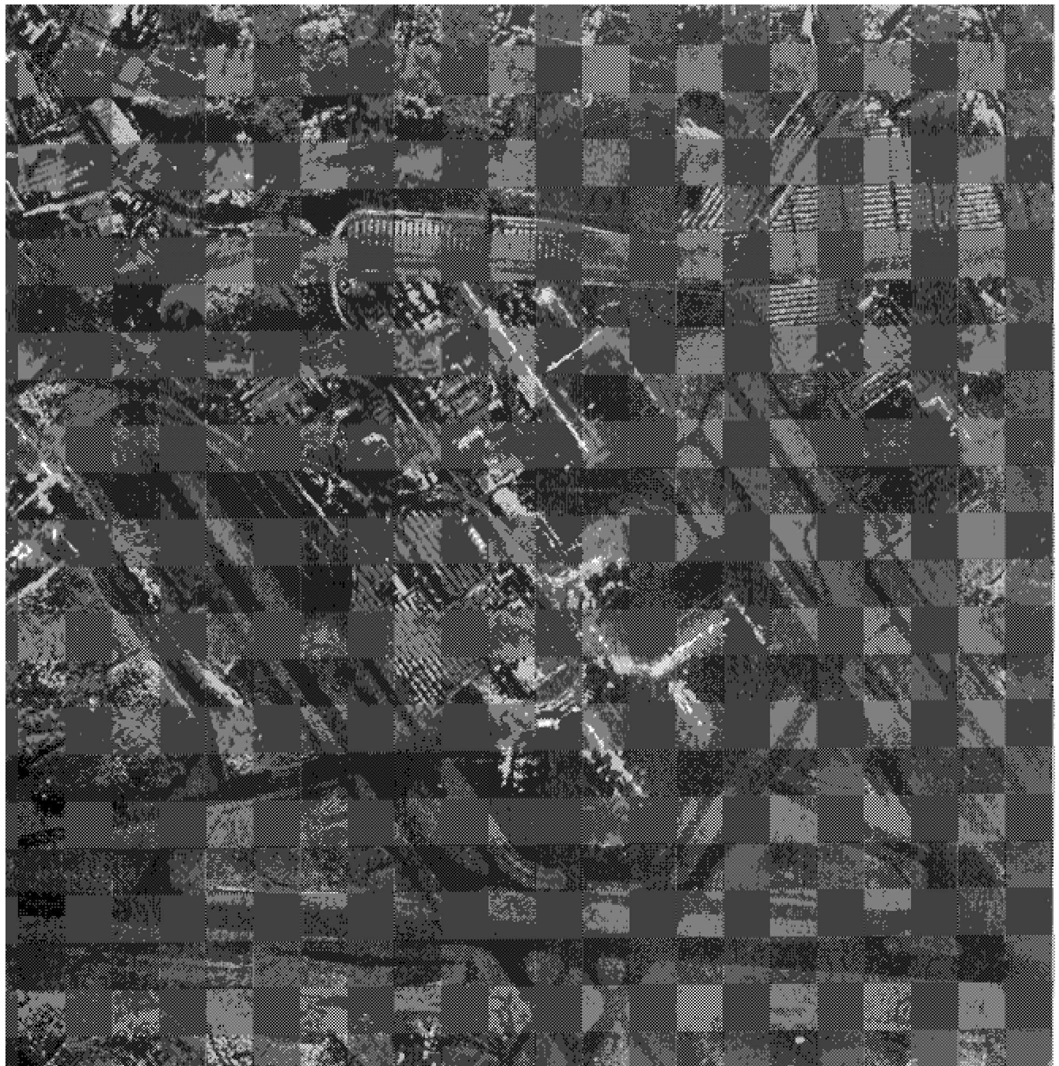


Scan SAR

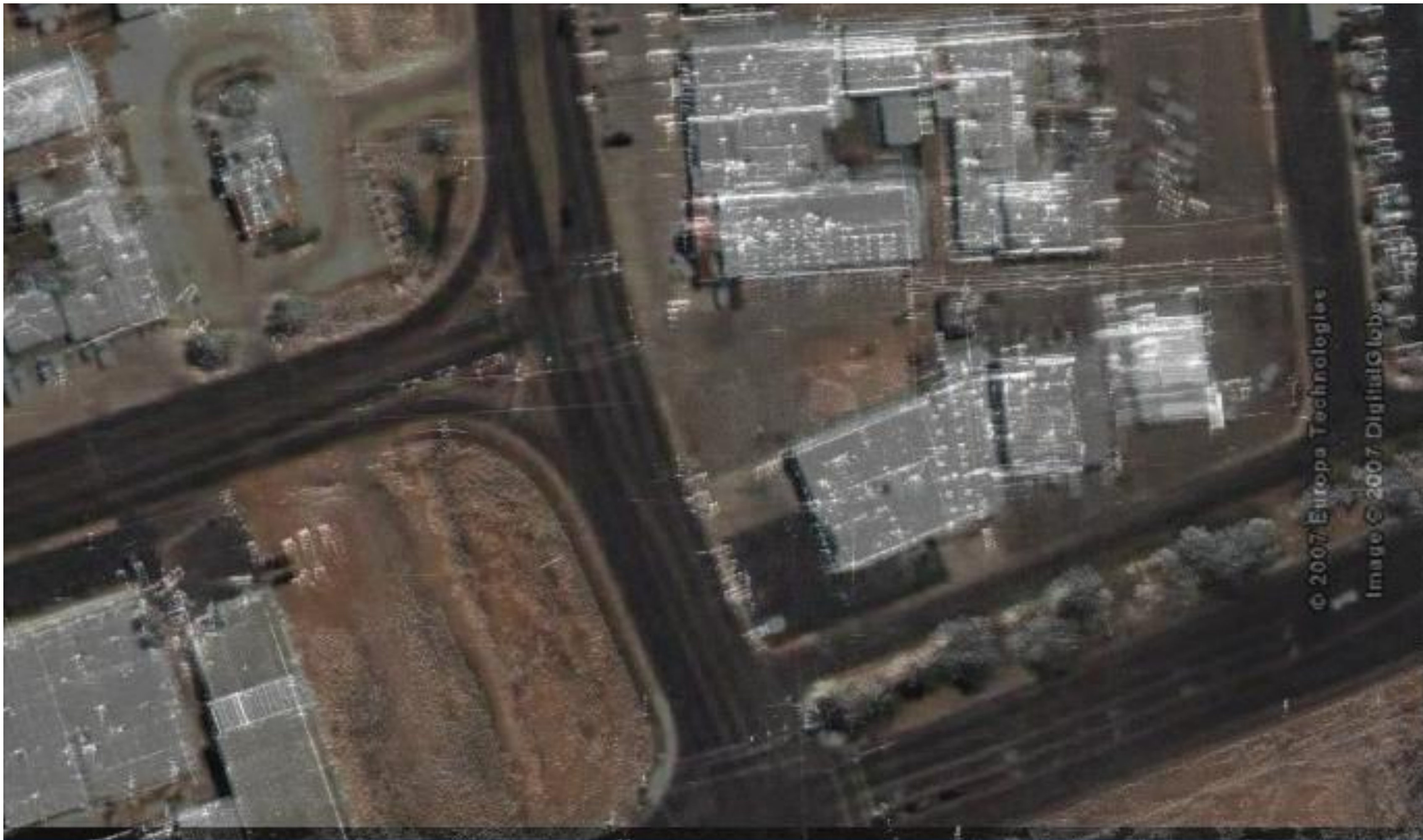
- One other (and seldom used) mode is scan SAR.
- The beam observes a straight strip of terrain that is not parallel to the flight path.
- Clearly such a strip must be of finite length, since eventually the range becomes so great that the SNR is too low to produce clear imagery.



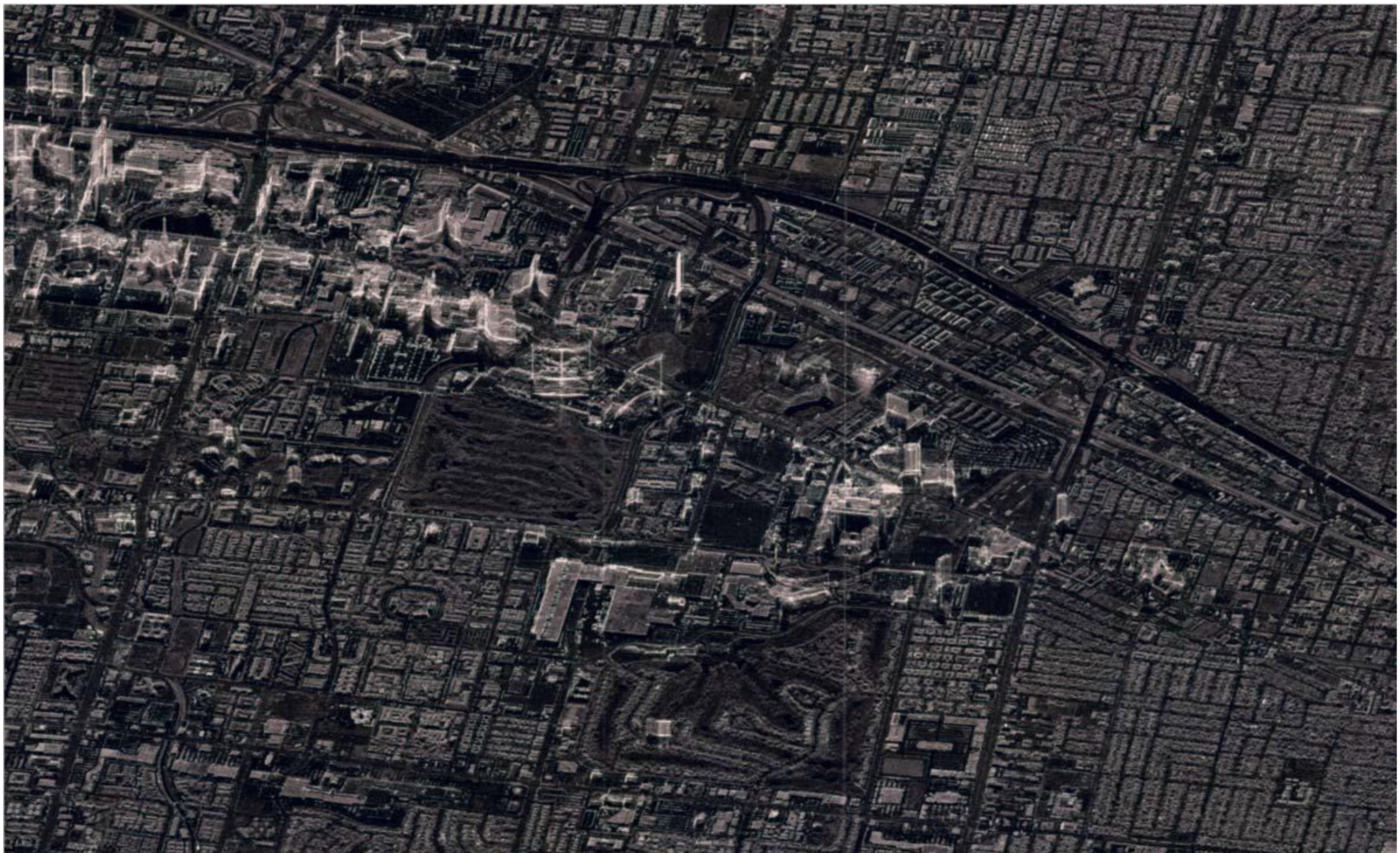
SAR Image of Baltimore-Washington International Airport



G. R. Benitz, Synthetic Aperture Radar (SAR), MIT Lincoln Laboratory, 2007.

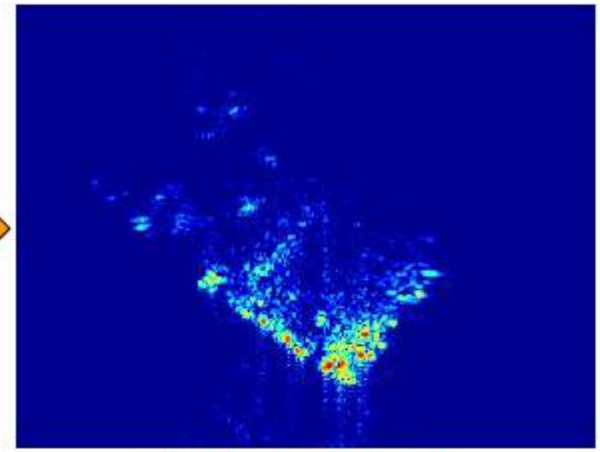


TerraSAR-X, Las Vegas, USA (time series of 20 images)

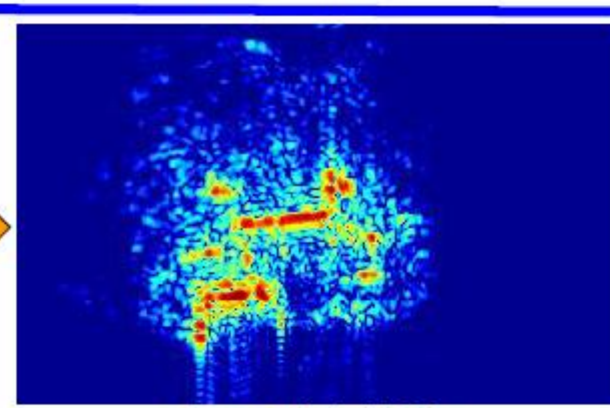


X-band, High Resolution Airborne SAR, F-SAR, Kaufbeuren, Germany

Other examples



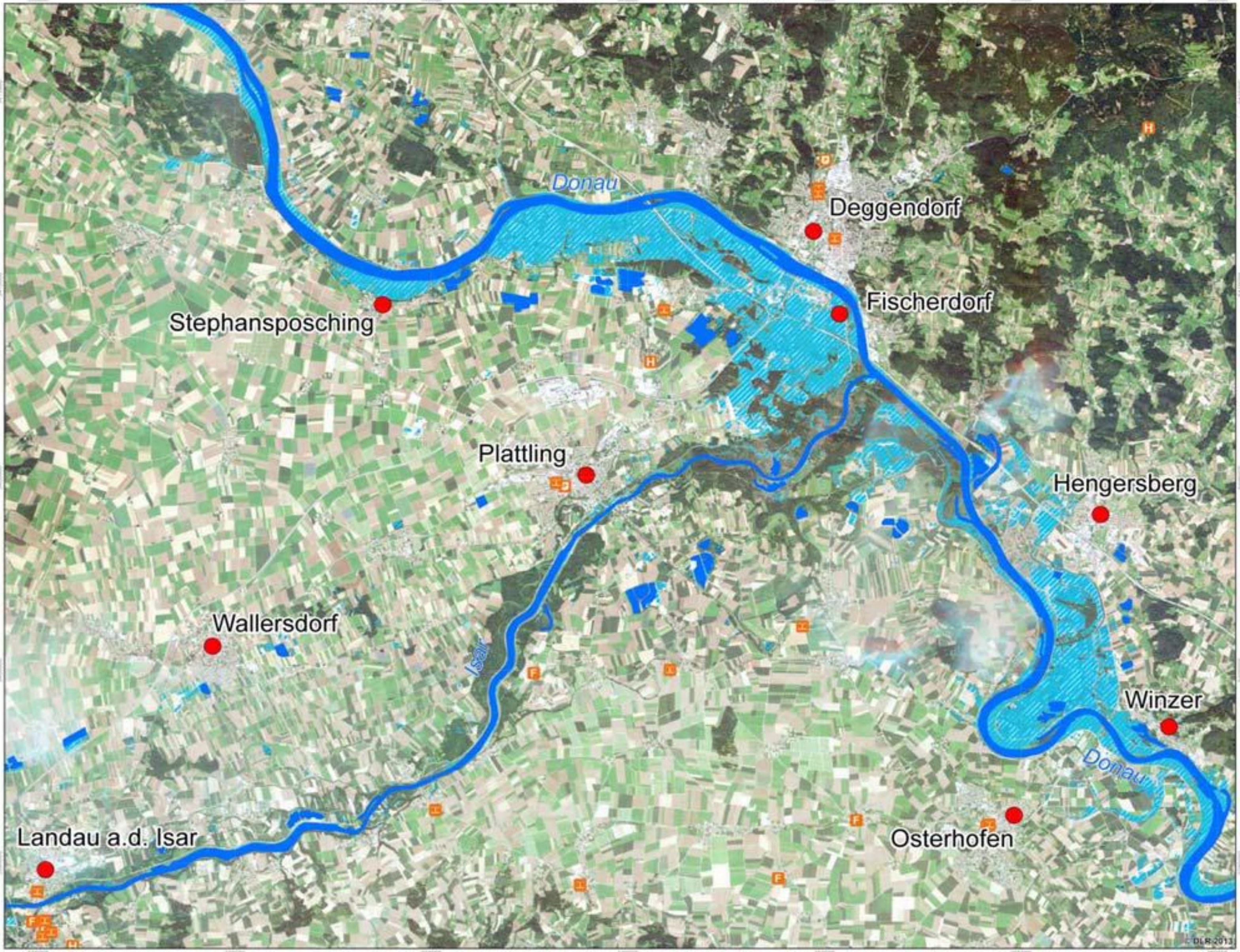
5.0 Mustang on radar



Cannondale M300

DEUTSCHLAND - Deggendorf

Hochwassersituation am 7. Juni 2013 - Betroffene Fläche - Übersicht 1: 45.000



Legende

Siedlung Wald Ackerfläche

Kritische Infrastruktur: Feuerwehr, Polizei, Krankenhaus, Schule

Bevölkerung: Stadt

Analyse:
- Referenzwassermaske DLM250
- Beobachtete Wasserausdehnung am 7. Juni 2013

Interpretation

Anhaltende Regenfälle haben in den vergangenen Tagen zu starken Überschwemmungen in weiten Teilen Deutschlands geführt. Die lokalen Einsatzkräfte werden von Bundespolizei, der Bundeswehr sowie dem Technischen Hilfswerk unterstützt.

Die Lage bleibt aufgrund sehr langsam sinkender Pegelstände weiter angespannt. Es besteht weiterhin Gefahr aufgrund der durchweichten Dämme. In den nächsten Tagen ist weiterer Niederschlag möglich.

Die in der Karte dargestellten Wasserflächen wurden aus einer TerraSAR-X-Szene mit einer räumlichen Auflösung von 3m abgeleitet, die am 07. Juni 2013 um 7:18 MEZ aufgenommen wurde. RapidEye Daten mit einer räumlichen Auflösung von 5m dienen als Hintergrundbild.

Kartographische Information

0 2 4 Kilometer

Projektion: UTM Zone 33N, Datum: WGS 1984
Geographische Projektion: Lat/Lon (DMS), Datum: WGS 84
Maßstab: 1: 45.000 für DIN A1.

Datenquellen

Hintergrund	© RapidEye www.rapideye.com
TerraSAR-X (3,0m)	© 2013 German Aerospace Center, 2013 Astrium Services /Infoterra GmbH
Wassermaske	© DLR 2013
Vektordaten	© GeoBasis-DE / BKG 2007_12 (www.bkg.bund.de) © OpenStreetMap - Mitwirkende

Rahmenbedingung

Die im Rahmen dieser Kartierung erstellten Produkte sind nach unserer besten Fähigkeit und neuestem Kenntnisstand realisiert worden.

Alle geografischen Informationen unterliegen Einschränkungen hinsichtlich des Maßstabes, der Auflösung, des Aufnahmedatums und der Interpretation der Ausgangsdaten. Durch den Produzenten wird keinerlei Haftung für die Inhalte oder deren Nutzung übernommen.

Die Krisenprodukte werden regelmäßig aktualisiert. Bitte besuchen Sie unsere Webseite (http://www.zki.dlr.de), um die aktuellste Version dieses Produktes zu erhalten.

Erstellungsdatum 07. Juni 2013

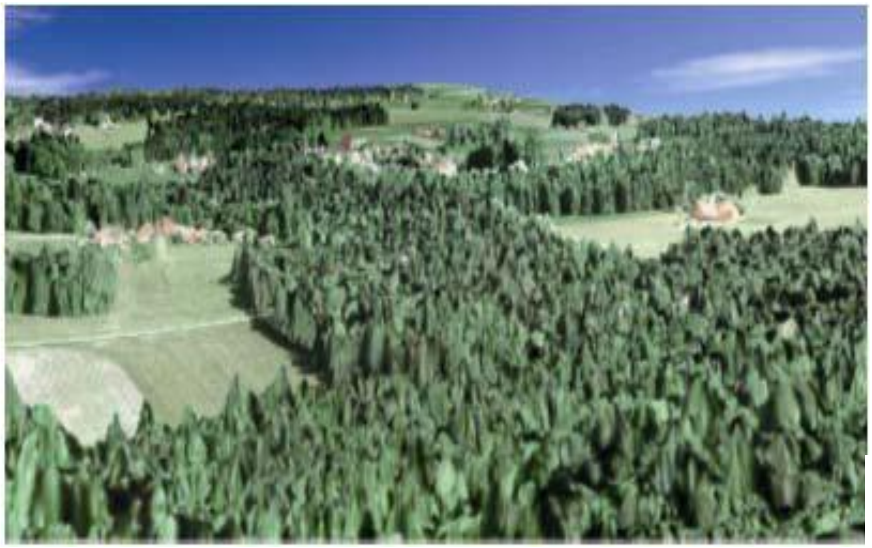
zki@dlr.de
http://www.zki.dlr.de

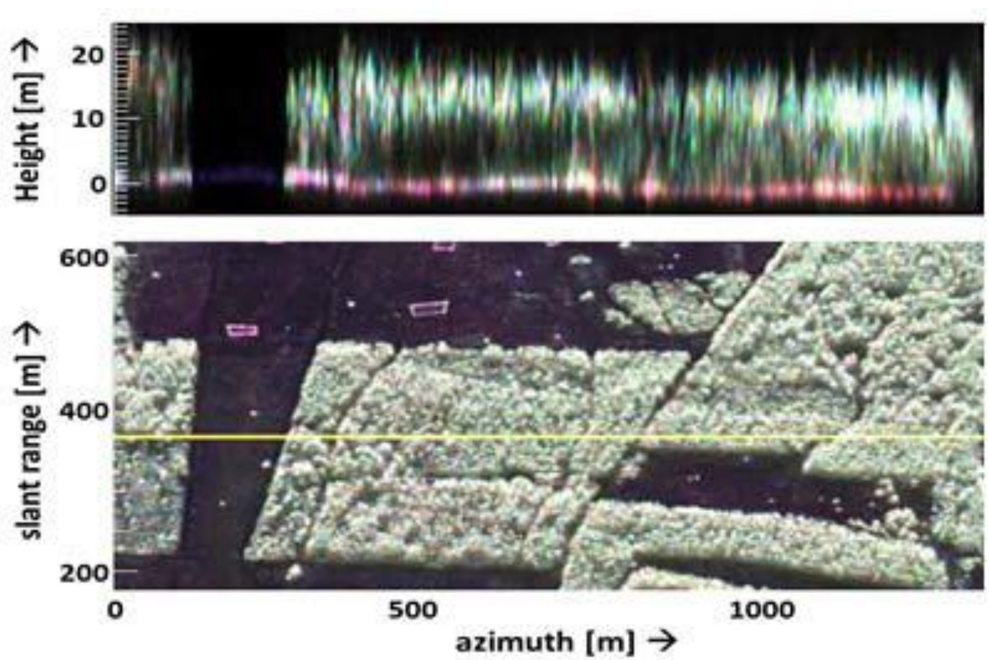
Zentrum für satellitengestützte Kriseninformation
- Notfallkartierung & Katastrophenmonitoring -

Deutsches Fernerkundungsdatenzentrum
Deutsches Zentrum für Luft- und Raumfahrt

DLR

Forest height with polarimetric SAR interferometry





How Does SAR Work?

- SAR produces a 2-D image.
- One dimension in the image is called range (or cross track) and is a measure of the "line-of-sight" distance from the radar to the target.
- Range measurement and resolution are achieved in SAR in the same manner as most other radars
- **Range is determined by measuring the time from transmission of a pulse to receiving the echo from a target and,**
- **Range resolution is determined by the transmitted pulse width, i.e. narrow pulses yield fine range resolution.**
- The other dimension is called azimuth (or along track) and is perpendicular to range.
- SAR ability to produce relatively fine azimuth resolution differentiates it from other radars.
- The sharpness of the beam defines the azimuth resolution.

GPR Sensor

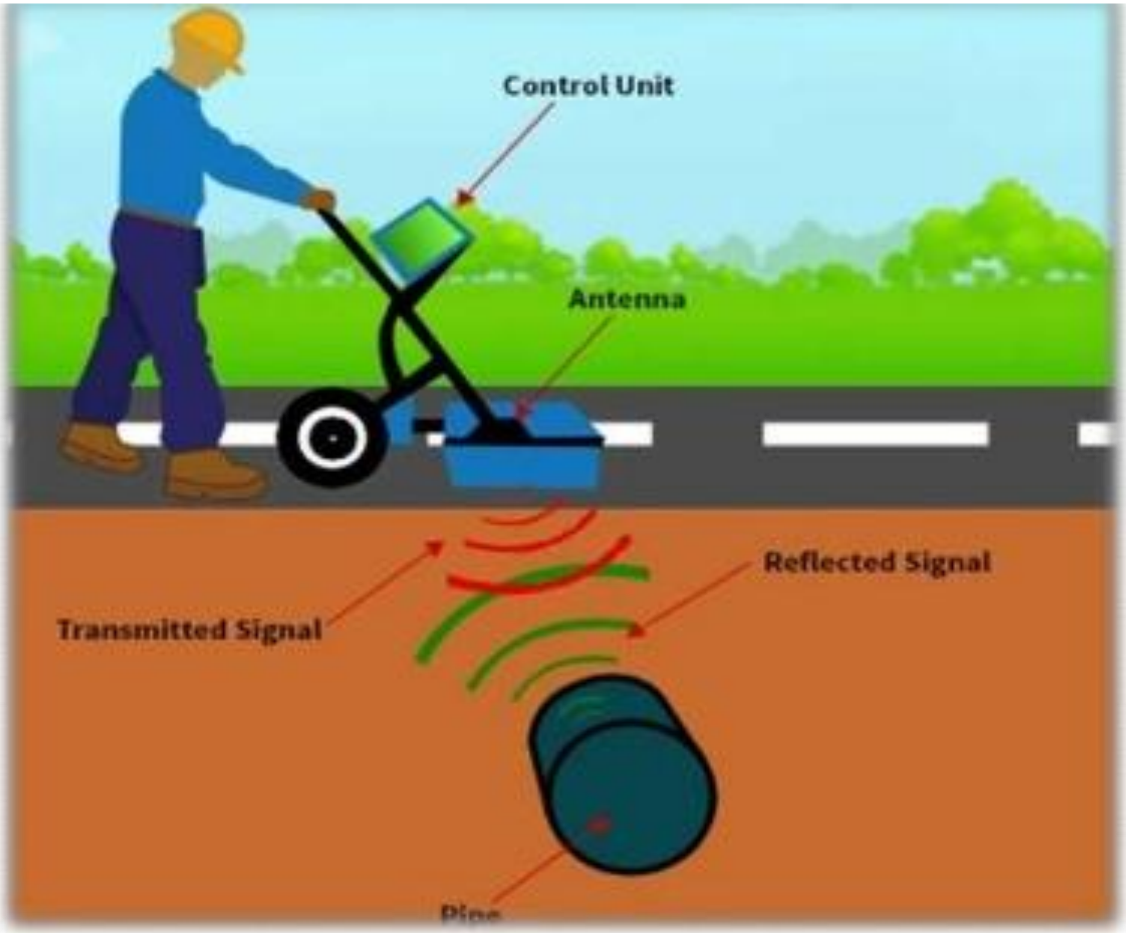
- GPR- Ground penetrating radar
- Also known as *ground-probing radar, sub-surface radar or surface-penetrating radar (SPR).*
- Allows the inspection of location of objects or interfaces buried beneath the earth's surface.
- Can also provide accurate depth estimates for subsurface objects.

Basic Operating Principle

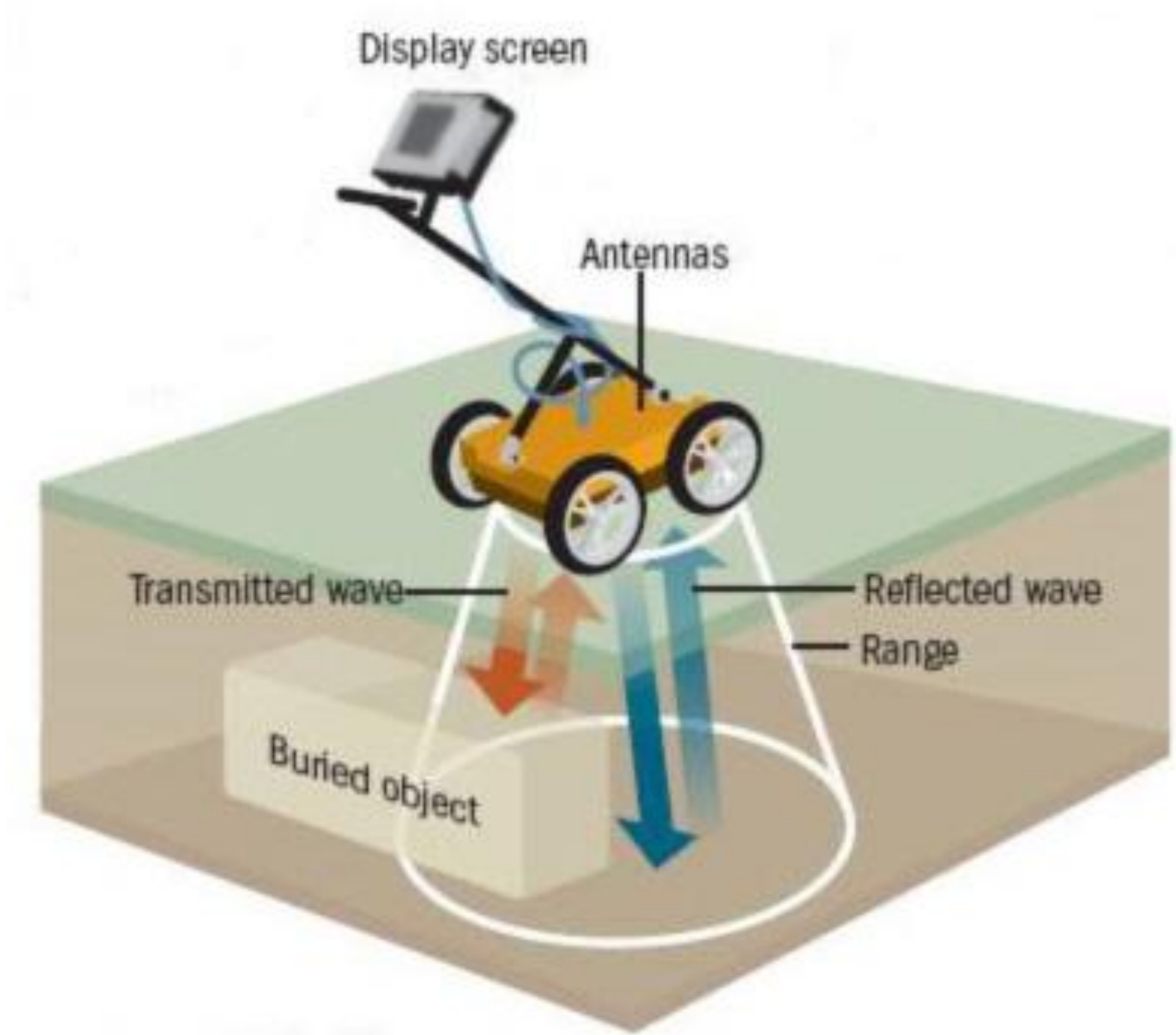
- GPR operates by transmitting microwave EM energy down into the ground through an antenna.
- The transmitted energy is reflected from various EM interfaces.
- An antenna then receives the reflected signal.

Components of GPR Sensor

1. **Transmitting and receiving unit**
2. **Control unit**
3. **Display unit**
4. **Power supplies**



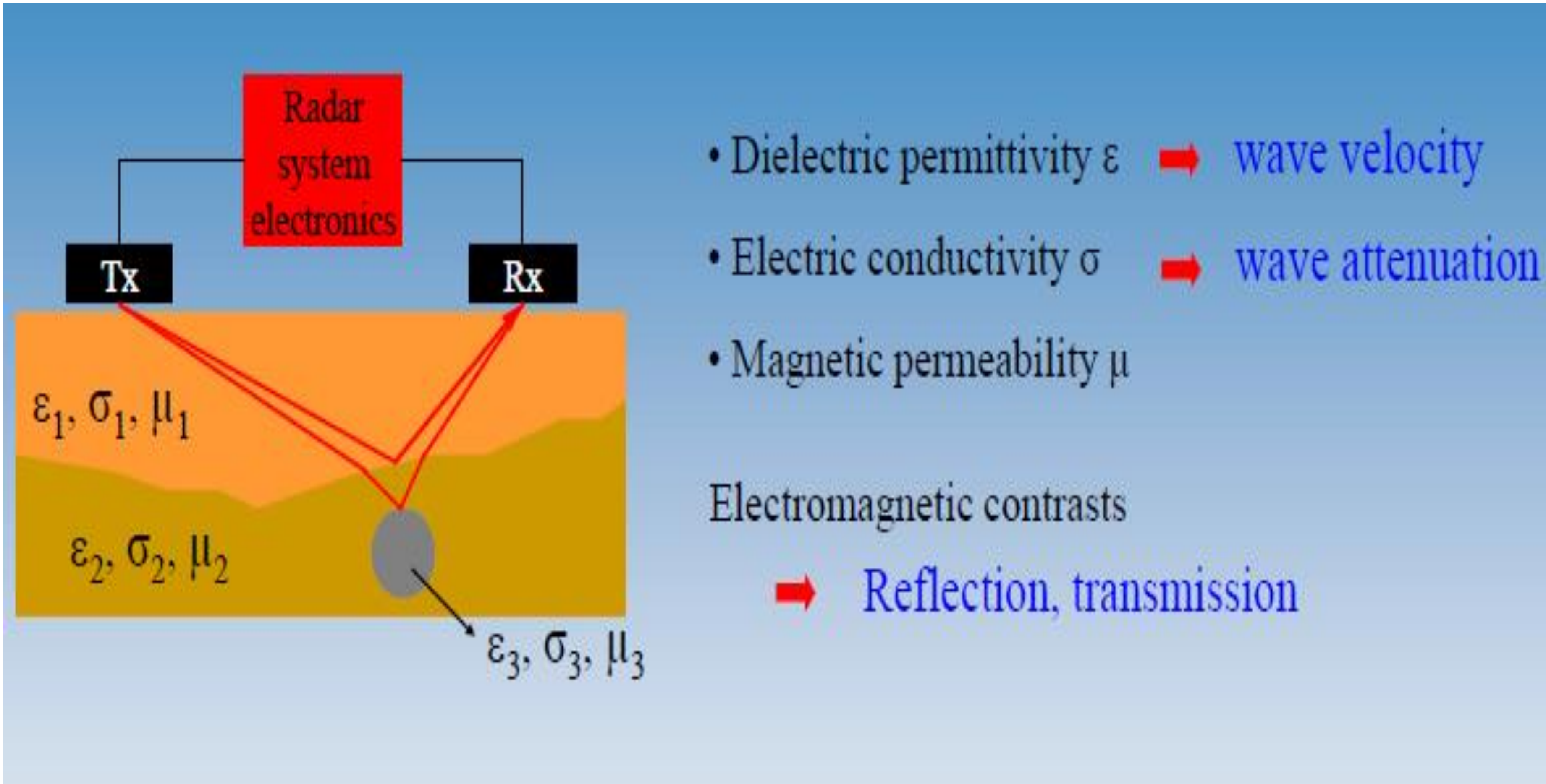
Contd.....


Display screen
Antennas
Transmitted wave
Reflected wave
Range
Buried object

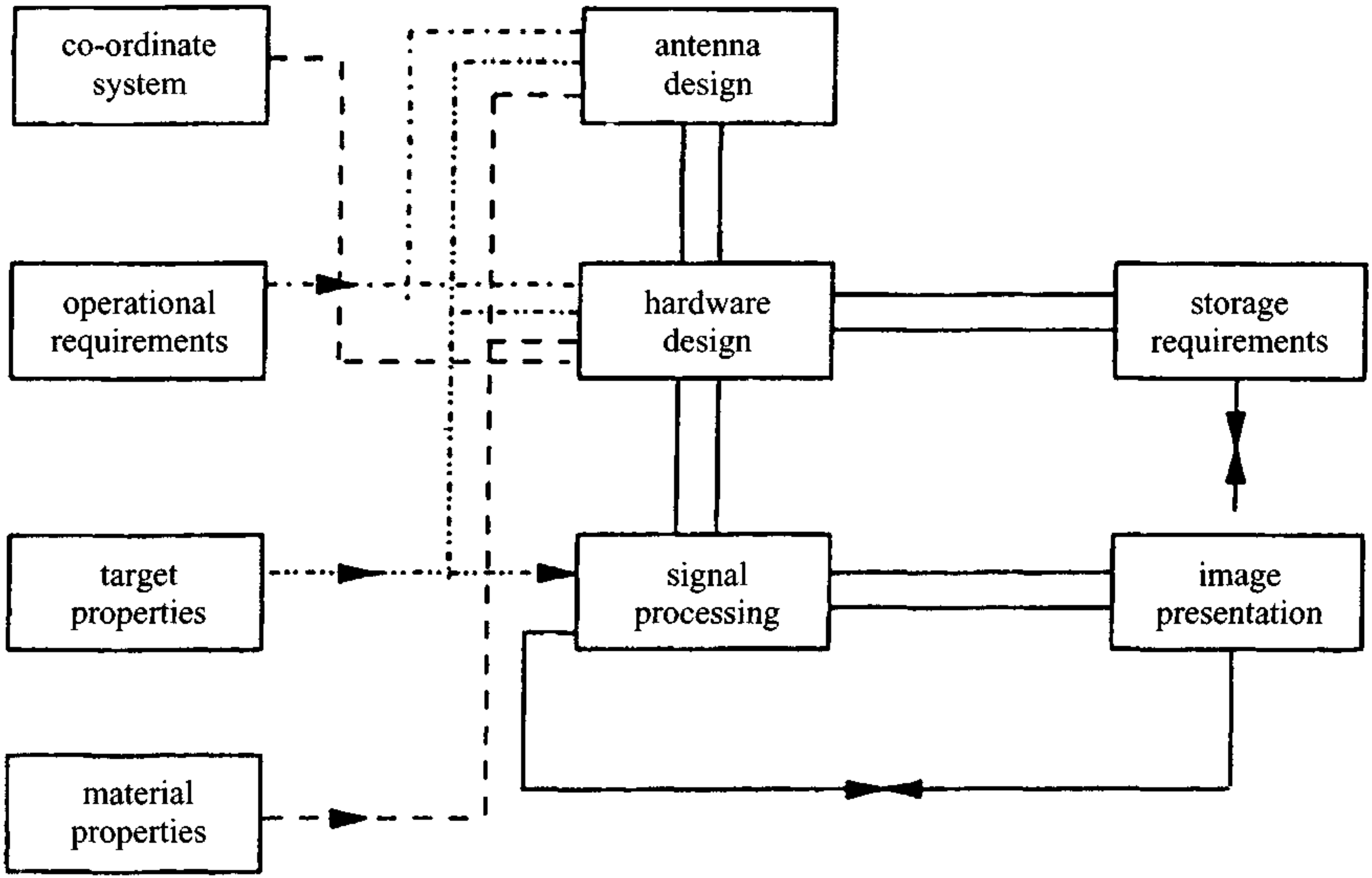
Contd......


Stepped frequencies:
0.5 - 2 GHz by 5 MHz
20 Transmit/Receive
antenna pairs

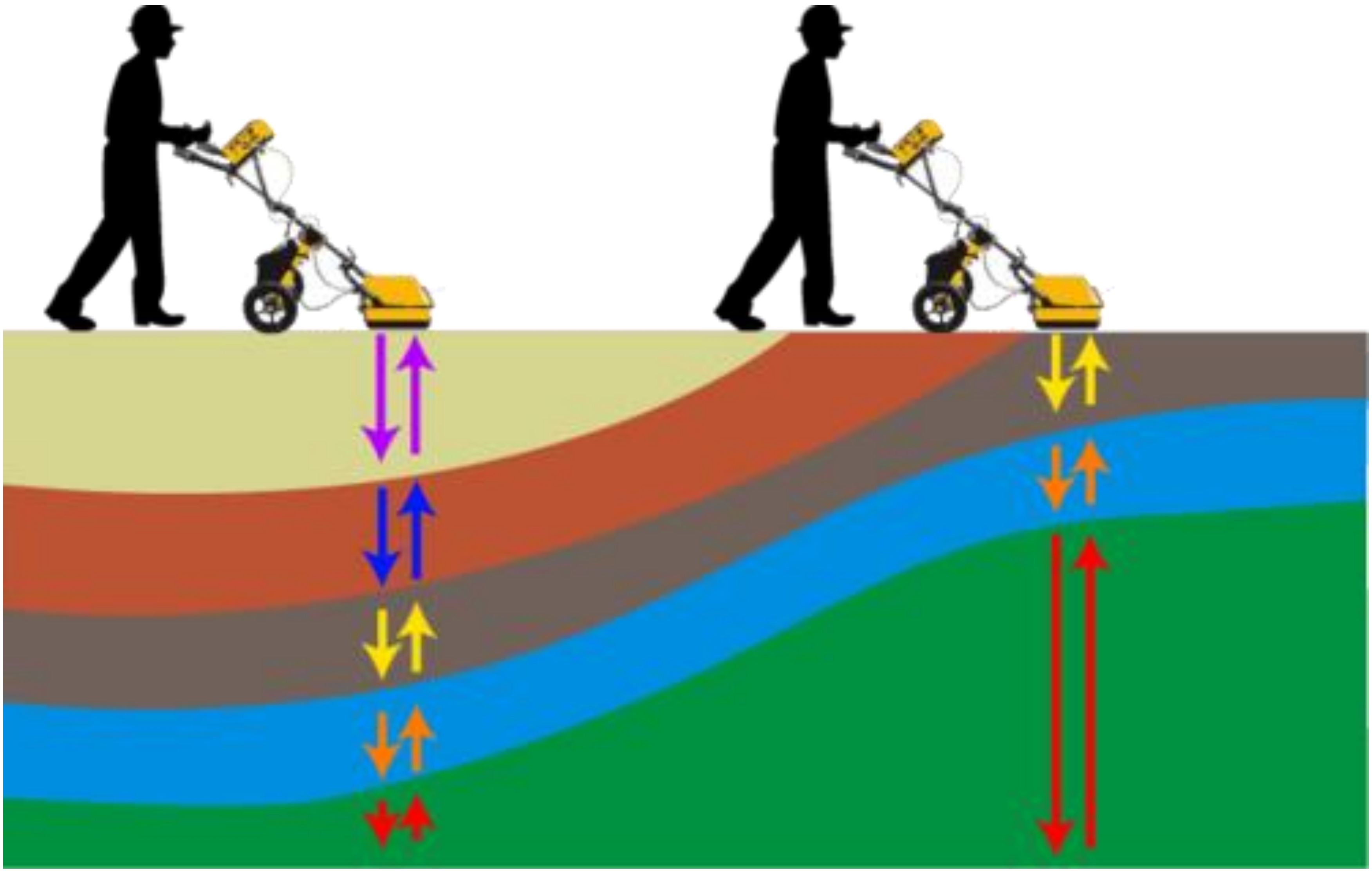
GPR Basic Principle

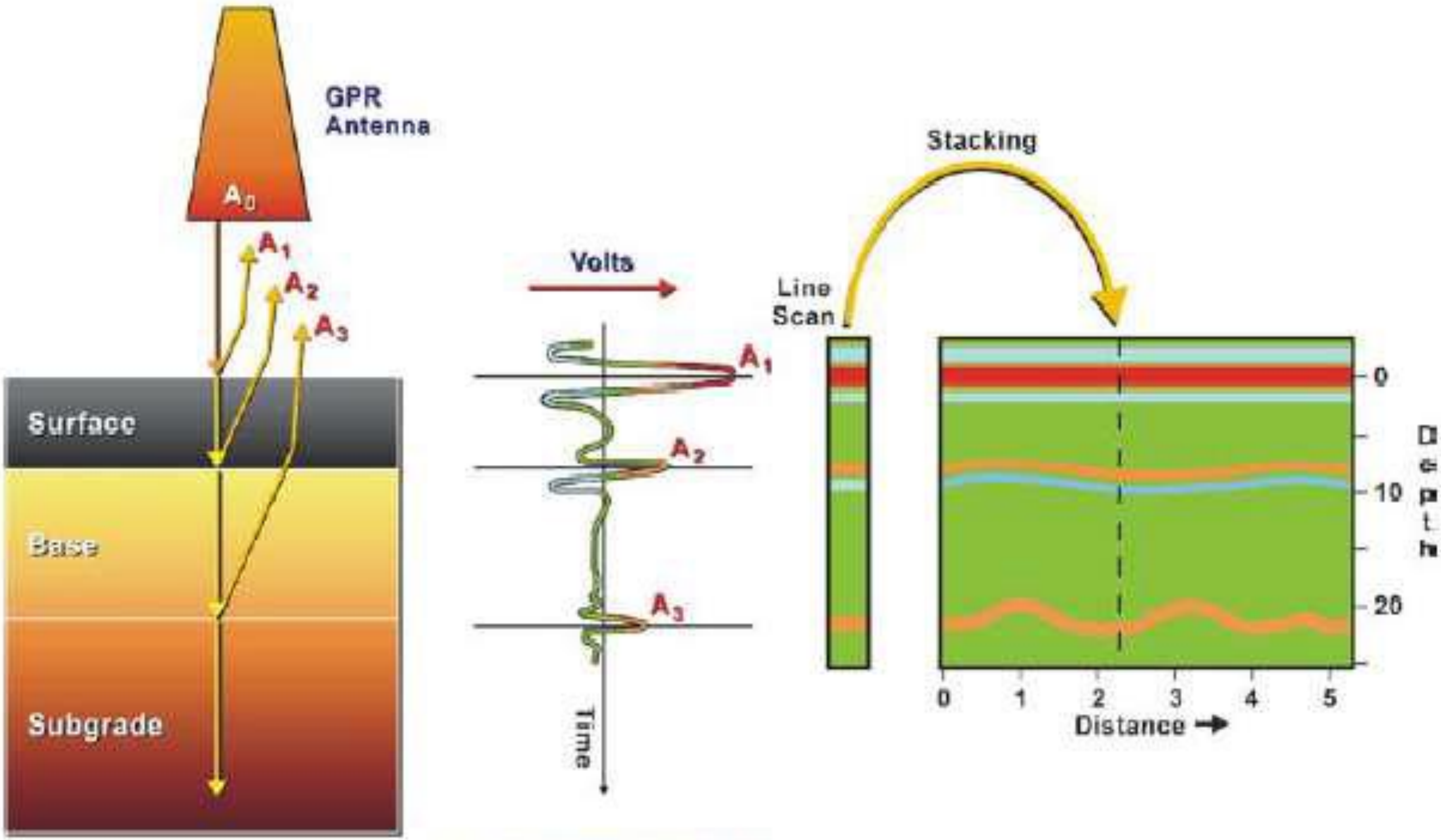


System Design Considerations



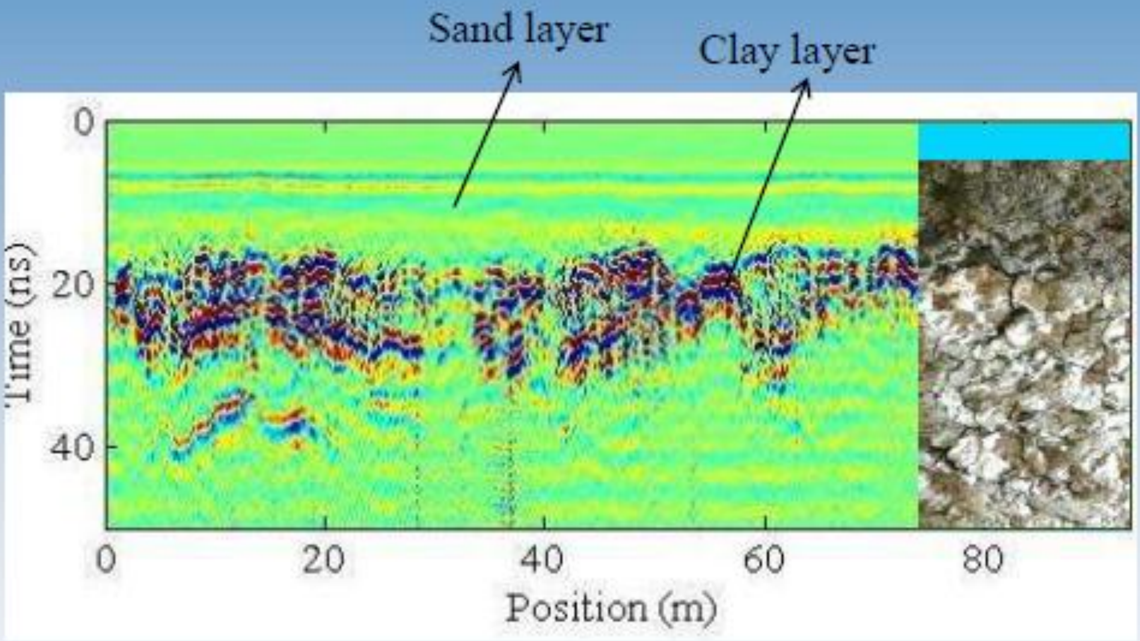
Principle Contd….



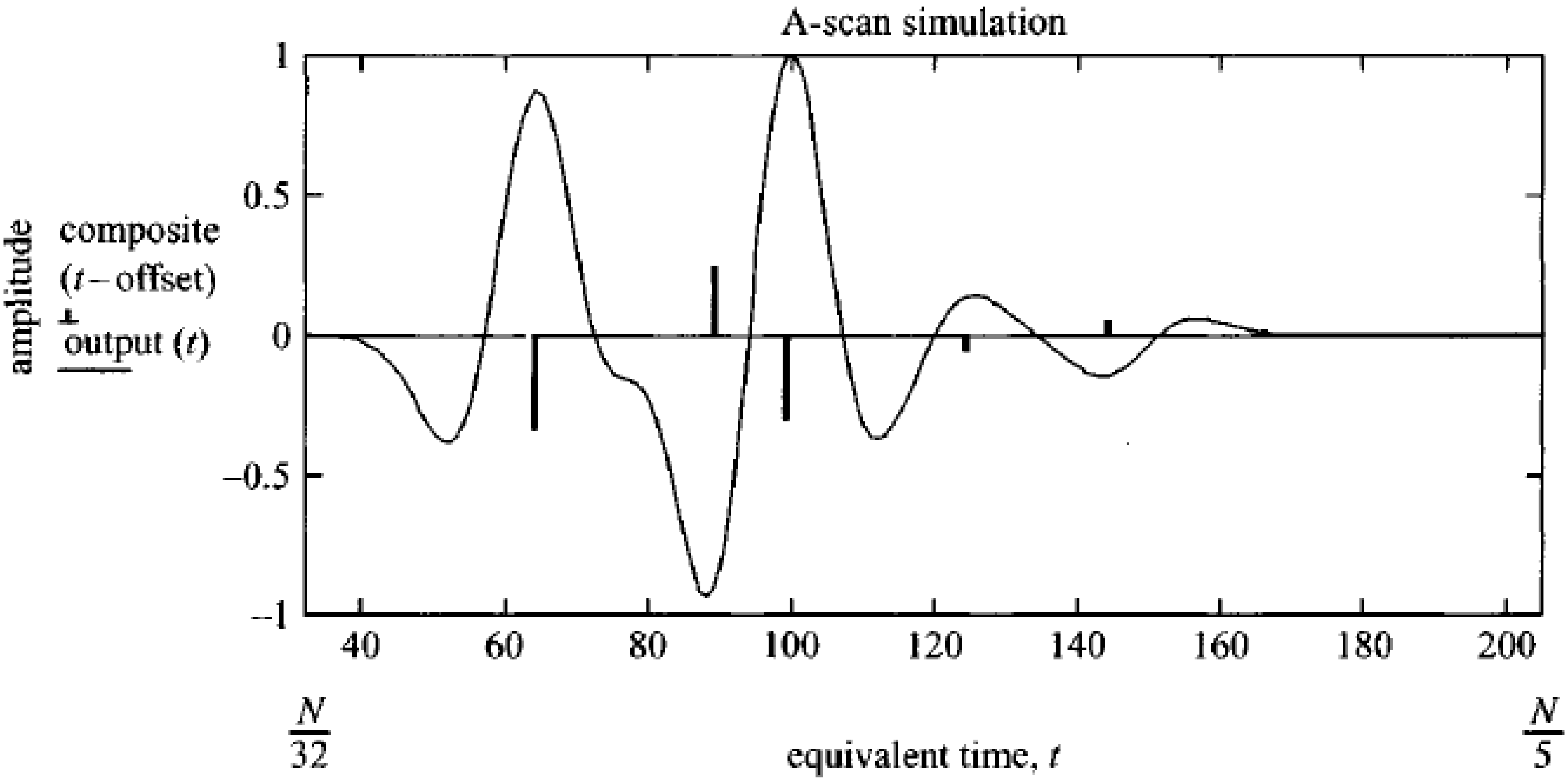


GPR
Antenna
A_0
A_1
A_2
A_3
Surface
Base
Subgrade
Volts
Time
A_1
A_2
A_3
Line
Scan
Stacking
0
10
20
Depth
0
1
2
3
4
5
Distance

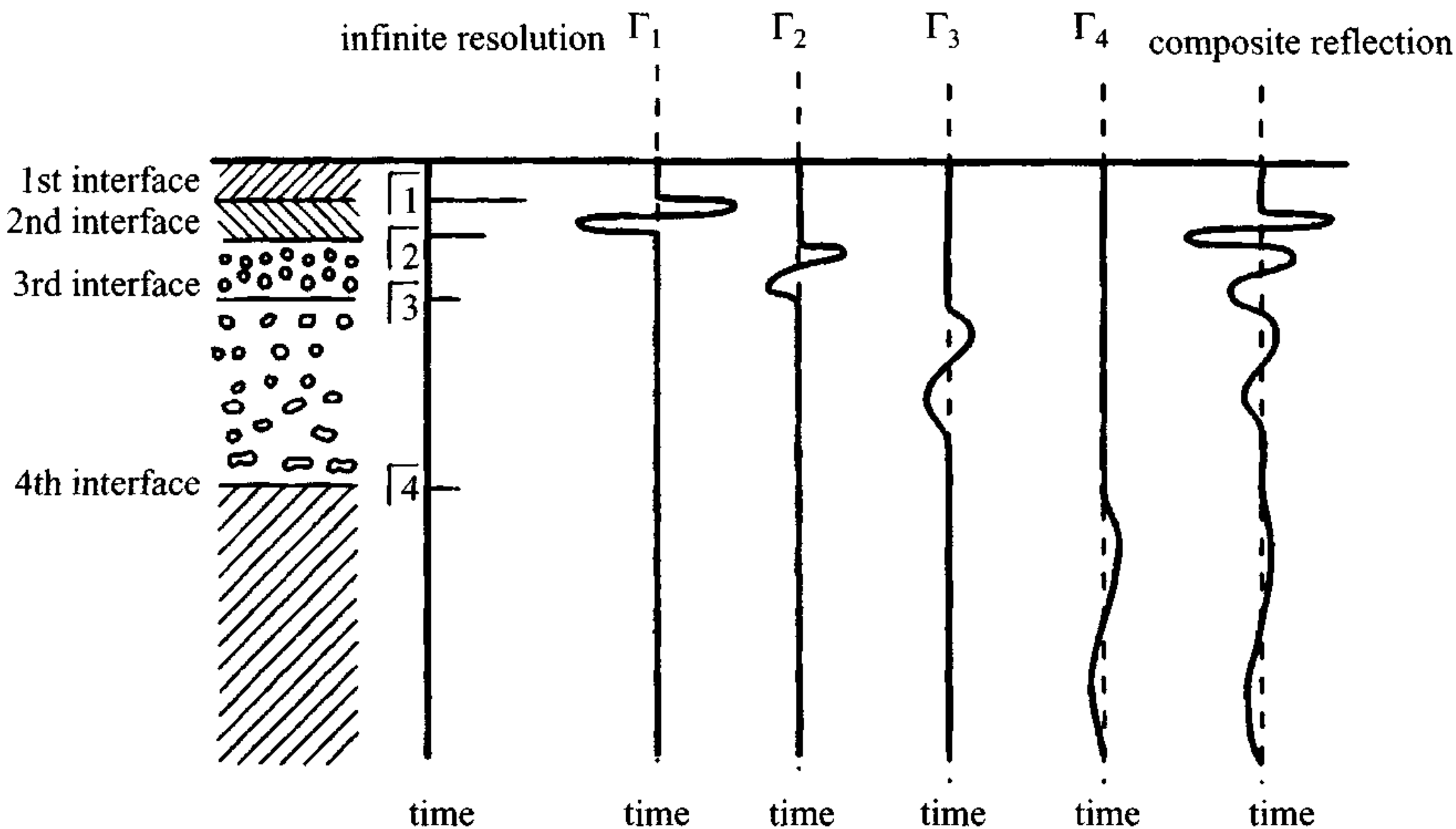
Example of GPR measurements in a vineyard (Saint-Emilion, France)



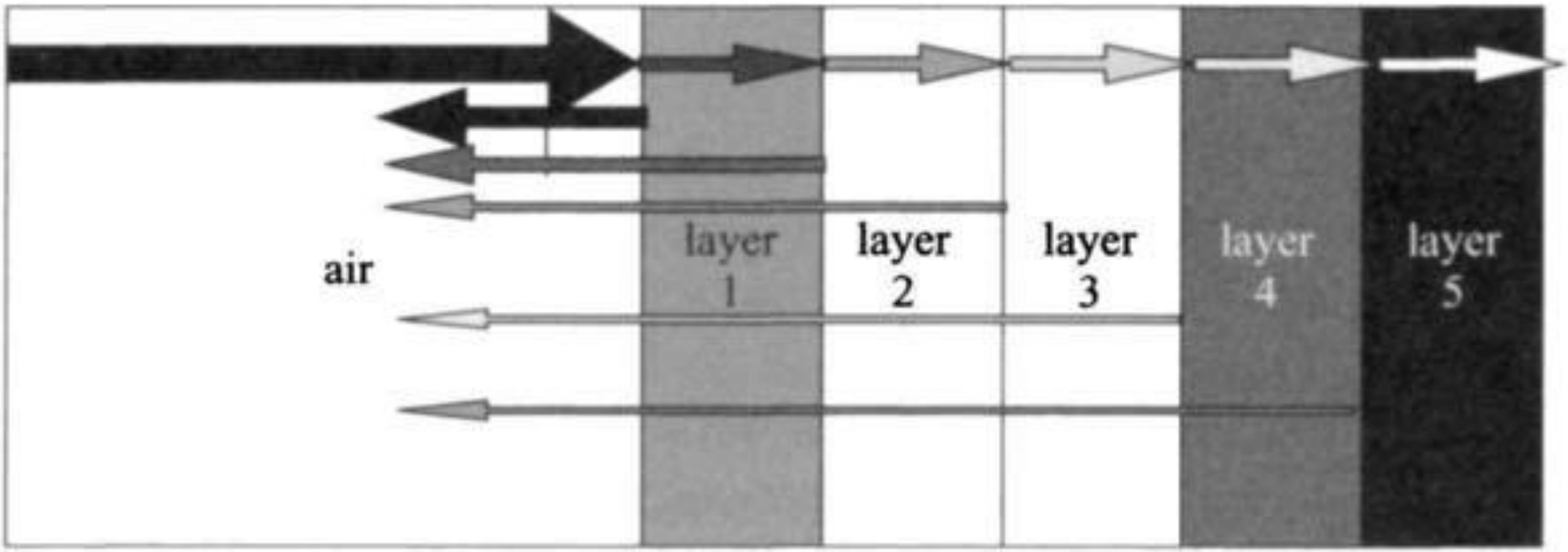
A-Scan of Target Using GPR



Convolution of multiple interface reflections



Layout of Transmission Line Model



Transmission and Reflection Coefficients of Multiple Layers

$$\rho_{01} := \frac{\eta_1 - \eta_0}{\eta_1 + \eta_0} \quad \tau_{01} := \frac{2\eta_1}{\eta_1 + \eta_0} \quad \rho_{10} := \frac{\eta_0 - \eta_1}{\eta_0 + \eta_1} \quad \tau_{10} := \frac{2\eta_0}{\eta_0 + \eta_1}$$

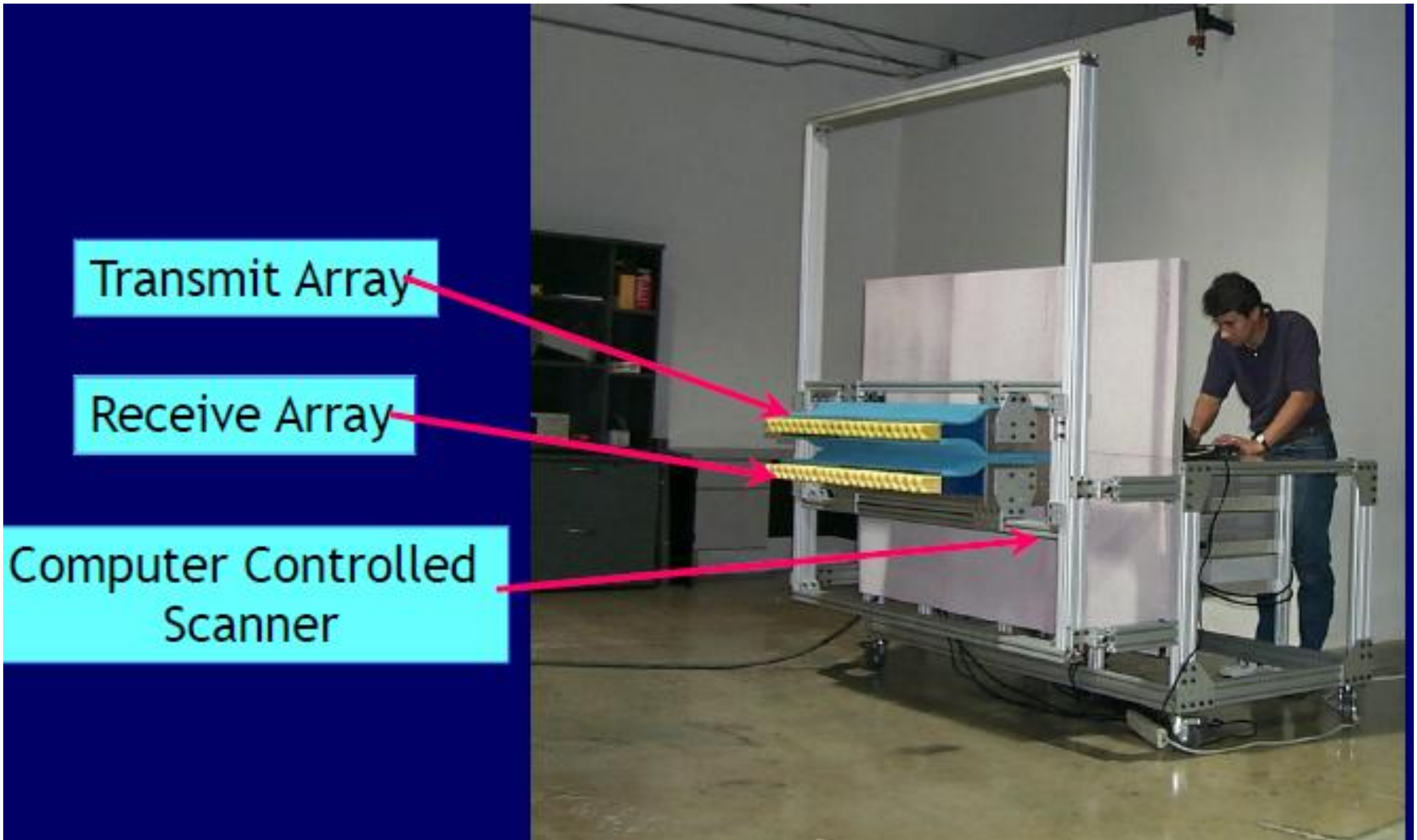
$$\rho_{12} := \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \quad \tau_{12} := \frac{2\eta_2}{\eta_2 + \eta_1} \quad \rho_{21} := \frac{\eta_1 - \eta_2}{\eta_1 + \eta_2} \quad \tau_{21} := \frac{2\eta_1}{\eta_1 + \eta_2}$$

$$\rho_{23} := \frac{\eta_3 - \eta_2}{\eta_3 + \eta_2} \quad \tau_{23} := \frac{2\eta_3}{\eta_3 + \eta_2} \quad \rho_{32} := \frac{\eta_2 - \eta_3}{\eta_2 + \eta_3} \quad \tau_{32} := \frac{2\eta_2}{\eta_2 + \eta_3}$$

$$\rho_{34} := \frac{\eta_4 - \eta_3}{\eta_4 + \eta_3} \quad \tau_{34} := \frac{2\eta_4}{\eta_4 + \eta_3} \quad \rho_{43} := \frac{\eta_3 - \eta_4}{\eta_3 + \eta_4} \quad \tau_{43} := \frac{2\eta_3}{\eta_3 + \eta_4}$$

$$\rho_{45} := \frac{\eta_5 - \eta_4}{\eta_5 + \eta_4} \quad \tau_{45} := \frac{2\eta_5}{\eta_5 + \eta_4} \quad \rho_{54} := \frac{\eta_4 - \eta_5}{\eta_4 + \eta_5} \quad \tau_{54} := \frac{2\eta_4}{\eta_4 + \eta_5}$$

Array based Sensor System



To operate successfully, GPR Sensor must achieve

- An adequate signal to clutter ratio
- An adequate signal to noise ratio
- An adequate spatial resolution of the target
- An adequate depth resolution of the target.

Applications

- Archaeological investigations
- Building condition assessment (evaluation of reinforced concrete)
- Contaminated land investigation
- Detection of buried mines (anti-personnel and anti-tank)
- Geophysical investigations
- Medical imaging
- Pipes and cable detection
- Rail track and bed inspection
- Road condition survey
- Security applications
- Timber condition
- Wall condition
- And many more…………..

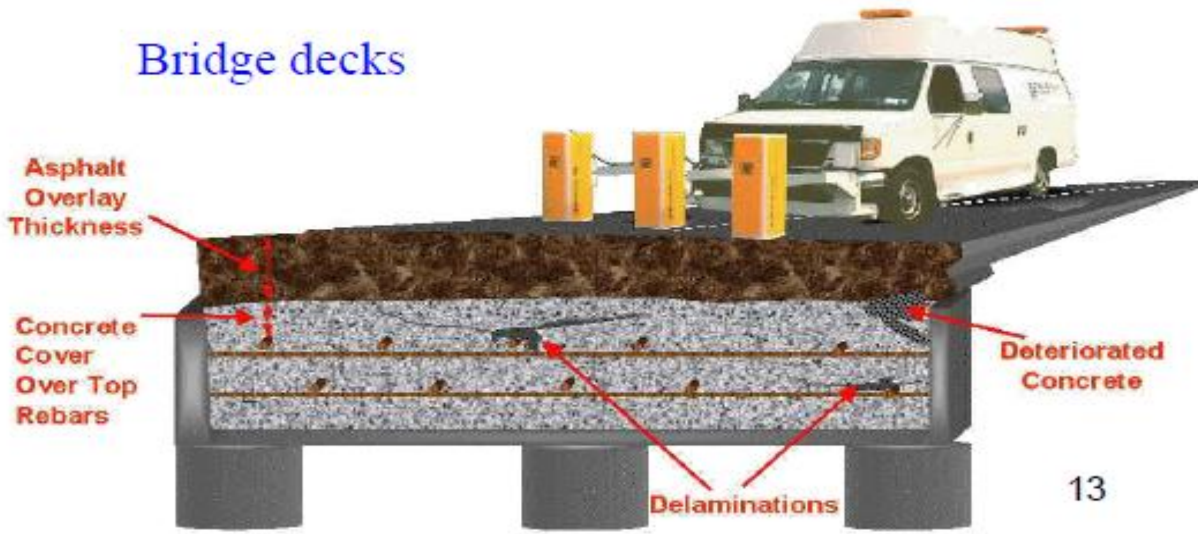
Applications of GPR Sensor

Roads, underground pipes and cables

Buried tanks

Tunnels

Bridge decks



Landmine detection

Handheld system

Through-Wall Imaging (TWI) Radar

- To detect the location of objects contained within a "wall," such as a concrete structure, the side of a bridge, or the wall of a mine.
- The ability to locate moving targets inside a building with a sensor situated at a standoff range outside the building would greatly improve situational awareness on the urban battlefield.
- A radar imaging system can be developed to image through walls, providing a down-range versus cross-range image of all moving targets at a video frame rate.

- Uses very short pulses to provide detection of objects on the opposite side of a non-metallic wall.
- The stimulus signal is transmitted into the wall.
- A portion of the signal incident on the wall is transmitted through the wall and into the space on the far side.
- Objects in the field then reflect the signal back to the wall where part of the signal is transmitted through the wall to the receiver.
- Freq of Operation: below 960 MHz or 3.1-10.6 GHz band.

TWI Radar

TWI Radar

Bi-static Radar for Target behind the Wall