

RADAR:

RADIO DETECTION & RANGING

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REMOTE SENSING IN the form of aerial photography has made extensive contributions to archaeology over the years, especially in identifying and mapping ancient sites. Such sites usually have dimensions measured in tens or hundreds of metres, and the high resolution afforded by aerial surveys makes such an approach very cost-effective. Spaceborne platforms generally have much poorer spatial resolutions and have not made significant contributions in the field of archaeology. However, the unique imaging capabilities of spaceborne radar systems have provided valuable information to archaeologists and will become increasingly important in the future.

Radar: theoretical concepts and systems

Radar (Radio Detection And Ranging) systems are active systems in that the satellite emits a pulse of long-wavelength electromagnetic radiation which illuminates the surface of the earth. When a radar signal intersects a target, it is reflected and scattered to a greater or lesser extent. A surface that scatters a large amount of the incident energy back towards the antenna on board the satellite is radar-rough because of its high radar return and will be assigned a bright signature on the image. If the transmitted energy is mainly reflected, very little electromagnetic radiation will be backscattered and this target is assigned a dark signature (radar-smooth). The transmitted and returned pulses of

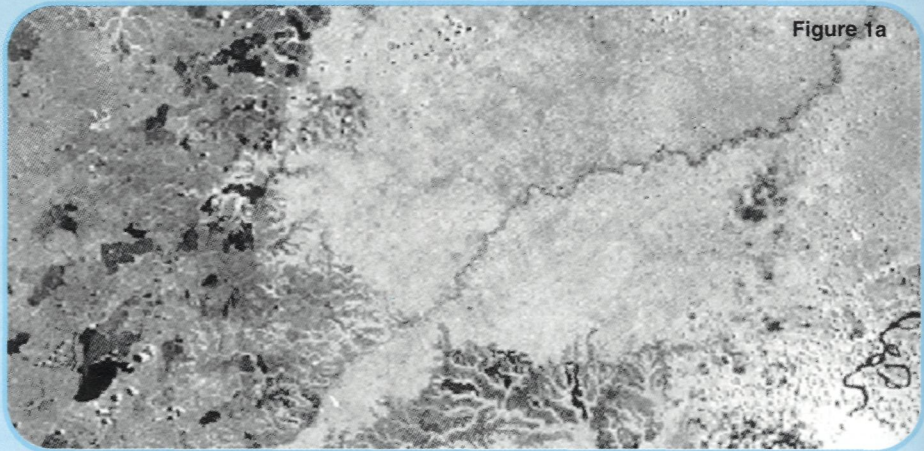


Figure 1a

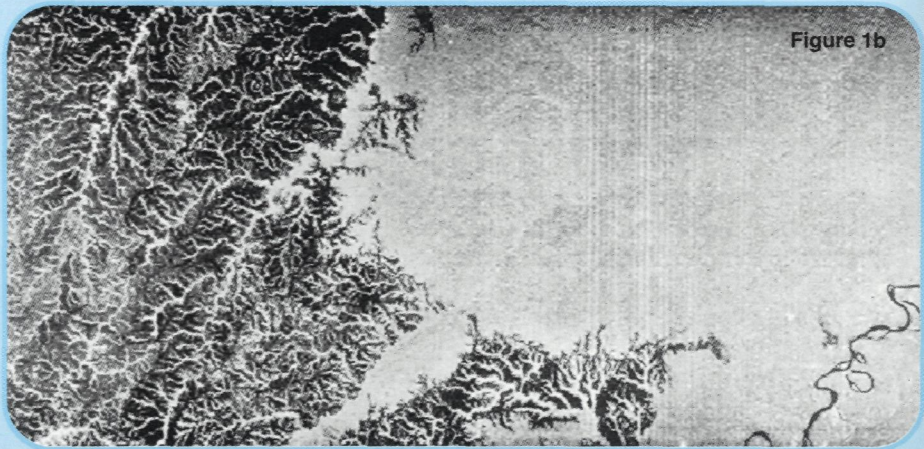


Figure 1b

electromagnetic radiation travel at the speed of light. The radar systems measure the time-lapse between transmitting and receiving the scattered pulse, which, because of the constant velocity of the wave, is a measure of how far the target is from the antenna.

Because the system carries its own source of electromagnetic radiation, unlike aerial photography, it is not dependent on solar illumination and may be operated at night. Aerial photography and remote-sensing satellites such as

Landsat generally obtain data within the visible or photographic infrared part of the electromagnetic spectrum (0.4–3.0 μ m). However, the wavelengths at which radar systems operate are more than 10,000 times longer than visible light and can often provide detailed information on areas which appear uniform at lower wavelengths. Part of Columbia as imaged by Landsat is shown in Fig. 1a. On this image, the dark-toned western region represents grassland and the pale area to the east is heavily forested. Little information can be obtained on

The application of spaceborne imaging radar for archaeological investigations

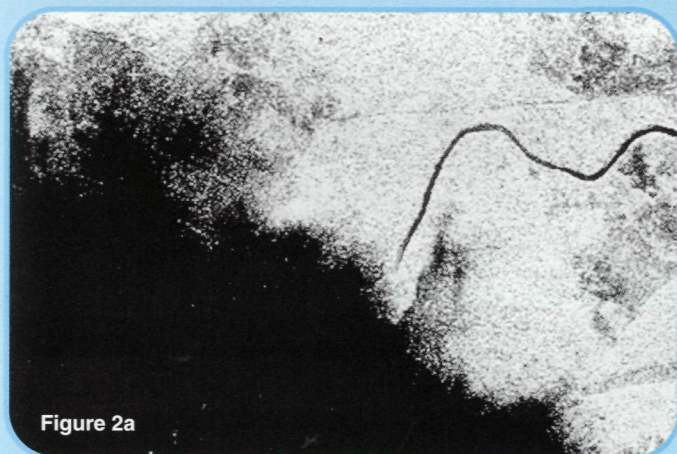


Figure 2a

Landsat for the grassland, but on radar the same region is seen to be dominated by extensive dendritic drainage networks (Fig. 1b).

Factors that control radar signatures

The signatures obtained by radar systems are a function of the operational wavelength and polarisation of the system and the surface roughness and dielectric constant of the terrain. Radar operates within the microwave range of the electromagnetic spectrum, which extends from 0.1cm to 100cm. Commonly used wavelengths are 3cm, 5.6cm and 23cm.

Short-wavelength radars are used in meteorological studies and for weather forecasting. These may be ground-based and detect the scattering from rain droplets within clouds. In order for satellite-based systems to have all-weather capabilities they operate at longer wavelengths, often approximately 23cm. The presence of a heavy rainstorm in the Brazilian forest is shown by a low radar return (black) using a short-wavelength radar (Fig. 2a). However, at a longer wavelength the radar can penetrate the rain and image the terrain, which is invisible at the shorter

wavelength (Fig. 2b). A great disadvantage of a satellite such as Landsat is that cloud cover may prevent data from being obtained for a particular area. Extensive and sustained cloud cover is particularly prevalent in tropical regions, and thus a region may not be imaged for years using passive sensors. Electromagnetic radiation at the wavelengths at which some radar systems operate can penetrate cloud and thus image the ground below.

The microwave radiation transmitted by radar systems is polarised with either a vertical or horizontal orientation. When this radiation intersects a target, a proportion of it can become depolarised owing to multiple reflections. This proportion will vary, depending upon the original orientation of the transmitted wave and the nature of the surface. The antenna measuring the radar return may be designed to measure either the return which has the same orientation as the transmitted wave or the depolarised radiation whose vector is at right angles to the transmitted wave. Thus a radar system may be a vertical transmit-vertical return (VV), horizontal transmit-horizontal return (HH), vertical transmit-horizontal return (VH), or horizontal



Figure 2b

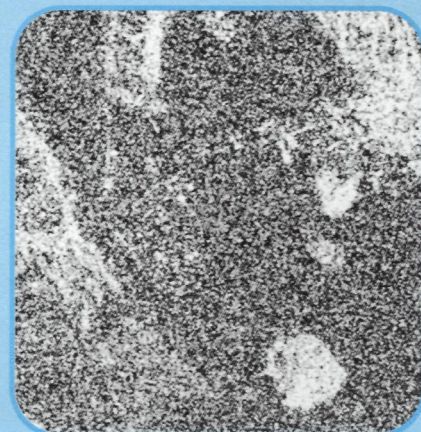


Figure 3a



Figure 3b

Figure 4a

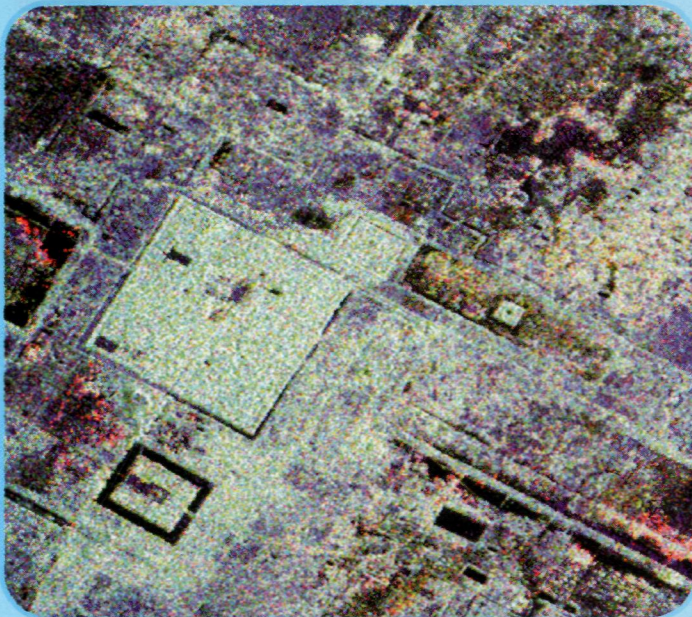
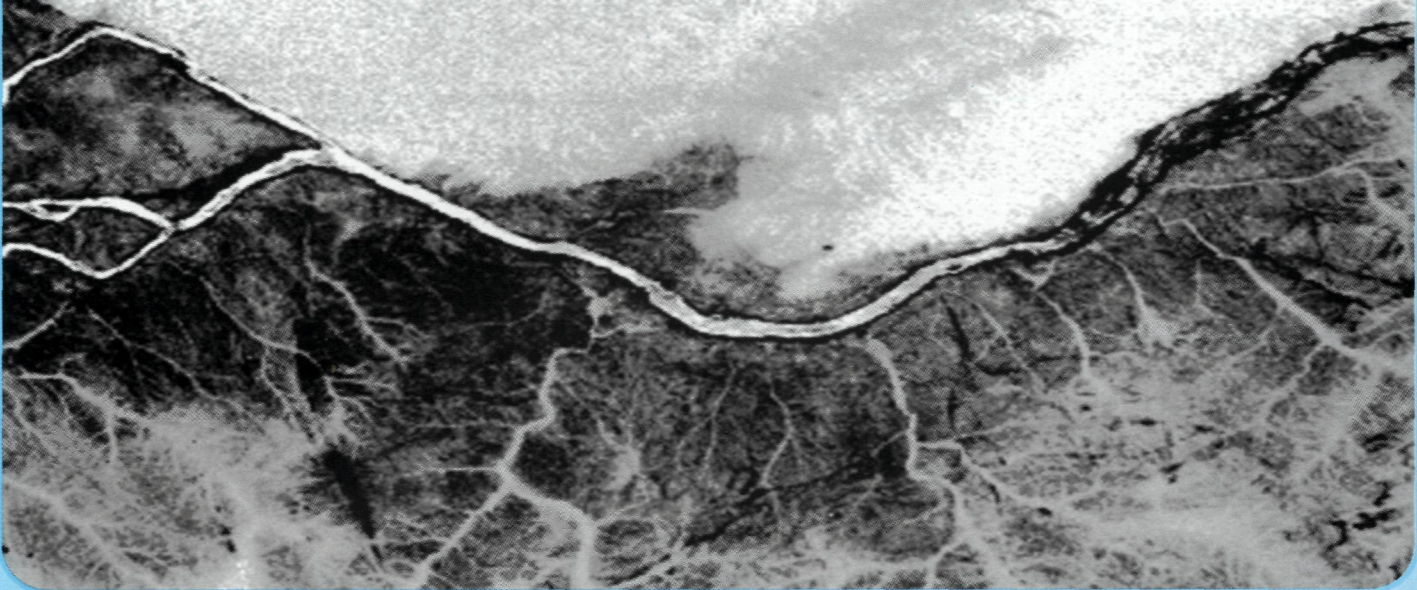


Figure 5

transmit-vertical return (HV).

The same target may produce different signatures depending on the particular combination of wavelengths and polarisations used. Figure 3a, taken from the space shuttle using a 6cm HV radar system, shows very little information. The same area imaged simultaneously with a 23cm HH radar is characterised by a very prominent bright linear feature that extends from

the top to the bottom of the image (Fig. 3b). This is part of the 3000km-long Great Wall of China, built approximately 600 years ago. Slightly to the right of the Great Wall another linear feature can be observed running parallel to it for some distance. This is part of a much older Great Wall, built 1500 years ago during the Sui Dynasty. The synoptic view provided by spaceborne radar is being used

to try to trace the continuation of this much older structure even when it is buried beneath sand.

Surface penetration by radar

Microwave electromagnetic radiation may, under certain conditions, be able to penetrate the surface of sand or soil. The depth of penetration is known as the radar skin depth. It decreases with increased values of the dielectric constant, which, because the latter is proportional to moisture content, means the drier the conditions the greater the penetration. In normal conditions, the amount of moisture in the sand or soil limits penetration to a few centimetres. However, in hyperarid areas, such as occur in parts of North Africa and the Middle East, penetration to much greater depths (2–3m) can be achieved. Figure 4a, taken in the visible range of the spectrum, shows a bend in the River Nile, to the north of which is a triangular sandy

region. However, radar can penetrate the sand to show the former course of the Nile as a pale linear feature (Fig. 4b). The presence of such palaeodrainage systems was unknown before the use of spaceborne radars. Field investigations of these former rivers have revealed unknown archaeological settlements in Egypt, which flourished when conditions were much wetter than today. When arid conditions developed, the sites were abandoned and buried beneath the sands of the Sahara.

Figure 5 is a colour spaceborne radar image displaying the Angkor Wat archaeological site in Cambodia. Temples in this region date back to the ninth century. The image is 18km wide. It should be remembered that this image was obtained through cloud and a thick rainforest canopy. Conventional photography would only show the tops of trees. Angkor Wat is the rectangle in the south-west



Figure 4b

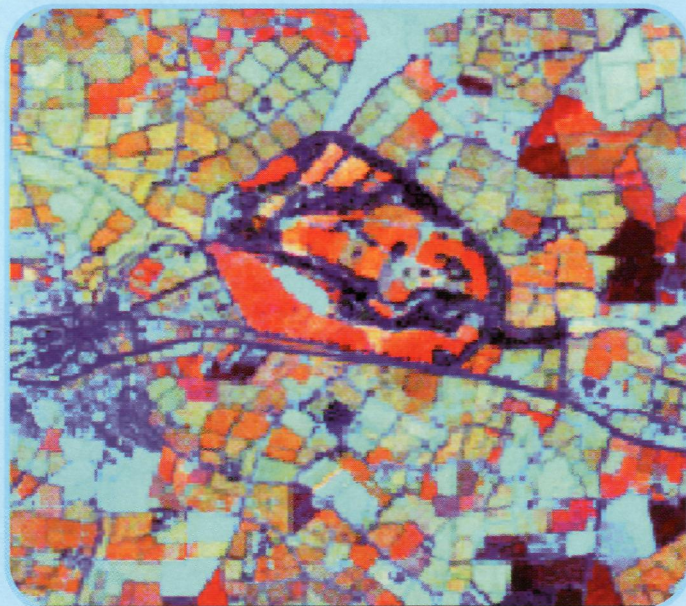


Figure 6a

corner surrounded by a black reservoir. The large square to the north of it is Angkor Thom. The regular outline of other temples, canals, irrigation channels, walkways and streets can also be determined from the image.

The unique imaging capabilities of radar have resulted in major archaeological discoveries in similar terrain. The 2000-year-old Mayan city

of Wakna was recently discovered in the rainforest of northern Guatemala, and in Oman the lost city of Ubar was discovered by means of remotely sensed data.

To date, radar imagery has not provided much archaeological information in Ireland, mainly because of the high moisture content of the soils. Figure 6a shows a conventional false colour satellite image of the

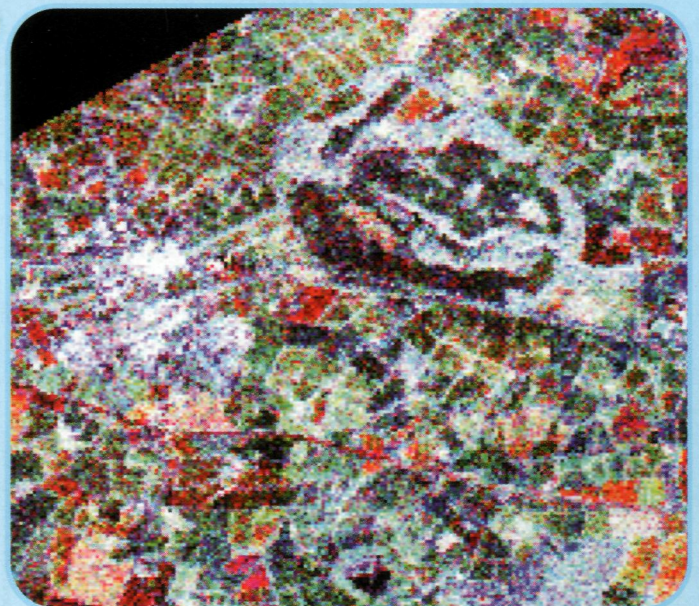


Figure 6b

Maynooth region. The town is the dark blue signature on the western edge of the image. The scene is dominated by the 1000-acre 250-year-old Carton demesne, which is the red elliptical feature. The checkerboard pattern of fields around it is very evident. Note the very regular large fields to the north of Carton, where hedgerows were removed over 100 years ago. Figure 6b is a

spaceborne radar image of the same area. This shows roughness variations, unlike the conventional satellite image which gives spectral differences. Little archaeological information can be obtained from this image.

ACKNOWLEDGEMENTS

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