N78-30470

SYNTHETIC APERTURE RADAR IN GEOSYNCHRONOUS ORBIT

KIYO TOMIYASU
GENERAL ELECTRIC COMPANY
VALLEY FORGE SPACE CENTER
PHILADELPHIA, PA. 19101

Radar images of the earth can be taken with a synthetic aperture radar (SAR) from geosynchronous orbital ranges by utilizing satellite motion relative to a geostationary position. See Figure 1. A suitable satellite motion can be obtained by having an orbit plane inclined relative to the equatorial plane and by having an eccentric orbit. Potential applications of these SAR images are topography, water resource management and soil moisture determination. Preliminary calculations show that the United States can be mapped with 100-m resolution cells in about 4 hours. With the use of microwave signals the mapping can be performed day or night, through clouds and during adverse weather.

Synthetic aperture radars have been flown in aircraft [3] and one is scheduled to be flown in the low-orbit NASA SEASAT satellite [1]. The antenna beam is usually oriented broadside (normal) to the radar platform velocity vector, although the beam can be oriented at other oblique angles [5]. The SAR image plane is defined by the platform velocity vector and radar antenna beam axis. A geometrical constraint requires that the normal of the object scene plane must not lie in the SAR image plane. In vector notation,*

$$(\bar{v} \times \bar{R}) \cdot \hat{n} \neq 0$$

where $\bar{v}$ = radar platform velocity vector

$\bar{R}$ = radar range vector along antenna beam axis

$\hat{n}$ = object scene plane normal

The track of a satellite in geosynchronous orbit depends on the orbit inclination angle and orbit eccentricity. In Figure 2a, a track is shown for an example of orbit inclination angle only. The long dimension is oriented in the North-South direction. If a small amount of orbit

* Other identities are $\bar{v} \cdot (\bar{R} \times \hat{n})$ and $\bar{R} \cdot (\hat{n} \times \bar{v})$.

eccentricity is added the track will tilt as shown in Figure 2b, and a greater eccentricity will produce the track shown in Figure 2c. With an inclination angle of ±1°, an orbit eccentricity of 0.009, and an argument of perigee of 90°, a near circular subsatellite track [2] can be produced as shown in Figure 2d, and the satellite scanning speed is about 48 m/se relative to a nominal geostationary position. The maximum range rate is about 30.4 m/sec to a 40° latitude ground location at the same longitude. A radar frequency of 2450 MHz, an antenna beamwidth of 1° and a ground resolution of 100 meters are assumed.

The following values were computed:

antenna diameter	7.3 m
incidence angle	46.3°
beam footprint	1063 km N-S by 654 km E-W
differential slant range across footprint	690 km
range ambiguity	217 pulses/sec, max
azimuth ambiguity	13 pulses/sec, min
radar PRF	54 pulses/sec, nominal
integration time	476 secs, min
radar bandwidth	2.08 MHz
radar Doppler shift	500 Hz, max

Depending on the viewing angle, an integration time of up to 700 seconds per beam footprint may be required. To achieve 100-m azimuth resolution to cover the United States, 3 East-West rows and 7 North-South columns of footprints will be required and this will take about 4 hours. The number of pixels is 10^9. An ambiguity due to a radar Doppler shift of 500 Hz can be removed by ground processing which relies upon accurate ephemerides data. An oscillator stability of better than 1 part in 10^{11} is required over the integration time. The time-delay Doppler shift signal processing technique required to produce images is quite similar to that used in radar astronomy [4].

The transmitter power was calculated assuming a system noise temperature of 600°K, a system loss of 6 dB and a resultant S/N = 10 dB. The average powers as a function of normalized radar cross section σ° are:

$\sigma°$, dB	P_{ave}, watts
-10	800
-20	8,000
-30	80,C00

Other sets of parametric values can be assumed to achieve different performance characteristics.

The author gratefully acknowledges the support provided by the National Aeronautics and Space Administration under Contract NAS-2-9580.

REFERENCES

[1] Brown, Jr., W. E., C. Elachi and T. W. Thompson, "Radar Imaging of Ocean Surface Patterns", J. Geophysical Res., Vol. 81, pp. 2657-2667, May 20, 1976.

[2] Chestek, J. H., General Electric Co., private communication.

[3] Cutrona, L. J., "Synthetic Aperture Radar," in Radar Handbook edited by M. I. Skolnik, New York: McGraw-Hill, 1970, Ch. 23.

[4] Green, Jr., P. E., "Radar Measurements of Target Scattering Propert'es," in Radar Astronomy edited by J. V. Evans and T. Hagfor s, New York: McGraw-Hill, 1968, Ch. 1.

[5] Kirk, Jr, J. C., "A Discussion of Digital Processing in Synthetic Aperture Radar," IEEE Trans. Aerosp. Electron. Syst., vol. AES-11, pp. 326-337, May 1975.

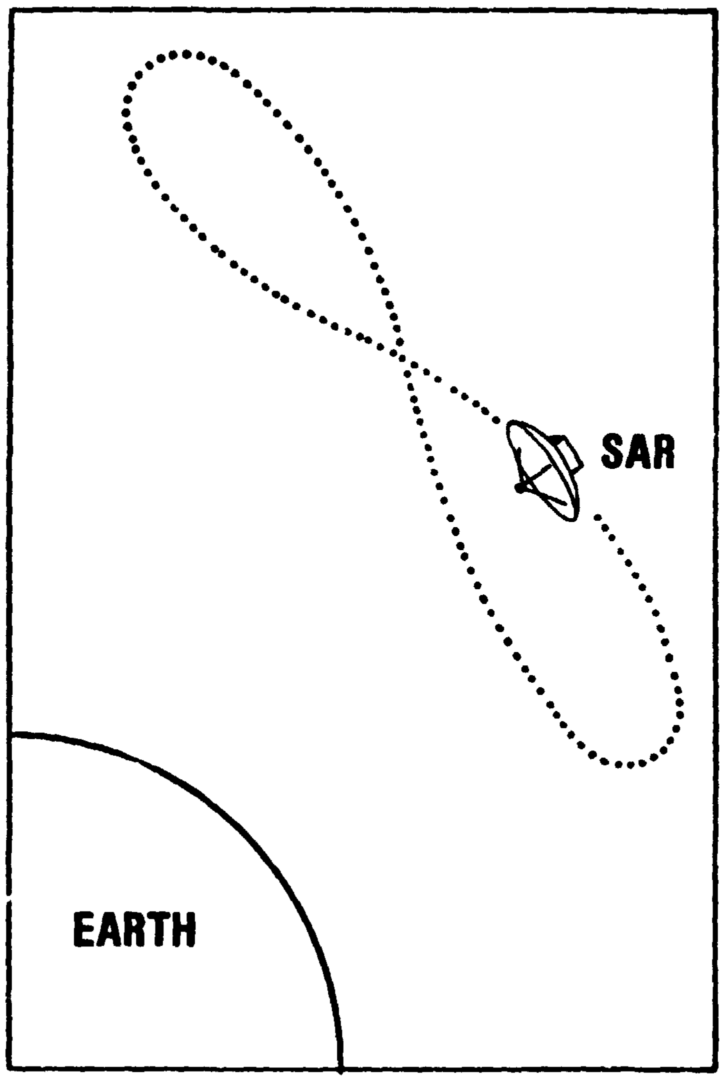

FIG.1 SAR GEOMETRY

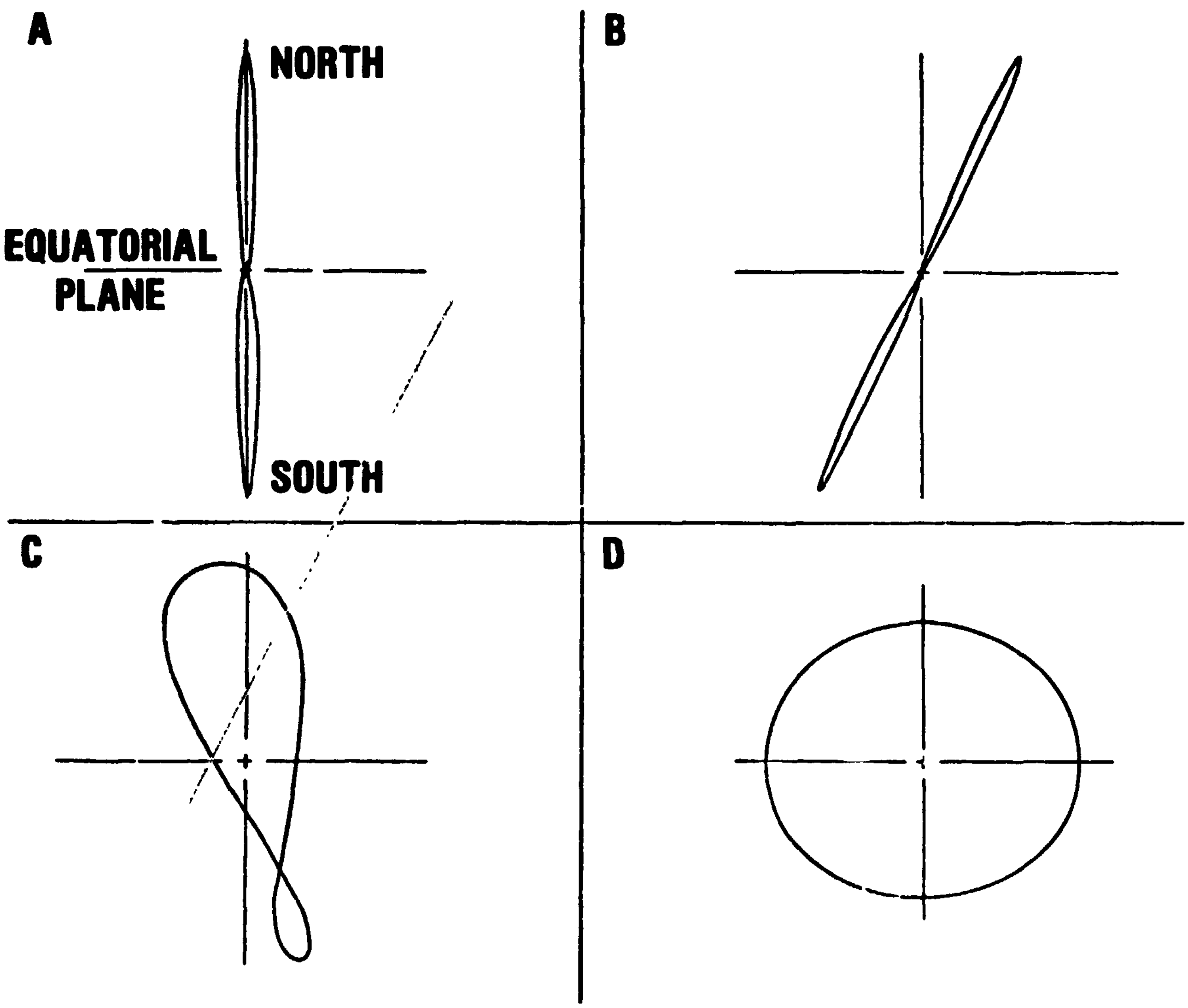

FIG.2 SUBSATELLITE TRACK