STAR Concept for Passive Microwave Temperature Sounding from Middle Earth Orbit (MeoSTAR)

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Abstract- **A future mission for a new microwave atmospheric temperature sounder radiometer in a Middle Earth Orbit (MEO) at 11,000 km altitude is described. The MeoSTAR design uses a stationary 1-dimensional Synthetic Thinned Array Radiometer in the 50-60 GHz microwave sounding band, to provide a "pushbroom" image as the satellite orbits. The advantage of this concept is an image with a high spatial resolution and a wide swath with no scanning antenna to disturb the visual and IR sensors on the same satellite.**

keywords - microwave radiometers, atmospheric sounding

I. INTRODUCTION[*]

A future mission for a new microwave atmospheric temperature sounder radiometer in a Middle Earth Orbit (MEO) at 11,000 m altitude is being studied by JPL for the NOAA, National Environmental Satellite Data and Information Service (NESDIS). The primary objective of this mission is to provide tropospheric temperature sounding in the 50-60 GHz band with a 50 km nadir spatial resolution, which will be used to enable cloud clearing for a matching IR sounder. To reach the surface at all latitudes and all clear and cloudy atmospheric conditions, the 50 GHz band is required. (The full system would also operate in the 183 GHz band to provide humidity soundings, and could also include imaging channels at 37 and 89 GHz.) A constellation of satellites will provide global coverage and near real time data and would complement the LEO sounders (AMSU and ATMS) because the sounding swath would be about 10,000 km.

II. INSTRUMENT CONCEPT

The MeoSTAR concept uses a 1-dimensional Synthetic Thinned Array Radiometer for each spectral band to provide a "pushbroom" antenna pattern, the yields an image as the satellite moves in its orbit. This is an application of a concept proposed by Doiron and Piepmeier in 2003 [1]. A stationary linear parabolic reflector with a diameter of 1.6 m and a length of 2 m would be the main antenna. This antenna would provide the along track spatial resolution of 50 km. A linear array of radiometers with an element spacing of 1.3 wavelengths would provide an unambiguous field of view of ± 22.5 degrees cross-track from the nadir. (At 11,000 km altitude, this is the angle of the Earth's limb.) The maximum spacing of the array of 246 wavelengths would provide the 50 km cross track resolution. To minimize mass, power and cost, the array would be thinned to have 30 elements, which would provide some redundancy. A sketch of this concept is shown in Fig. 1. The thinned array of 30 radiometers will be correlated to synthesize the cross track image. A 1-bit correlation system is used to minimize power. The slow ground velocity of 1.8 km/sec will allow long integration times to minimize the RMS noise or ΔT.
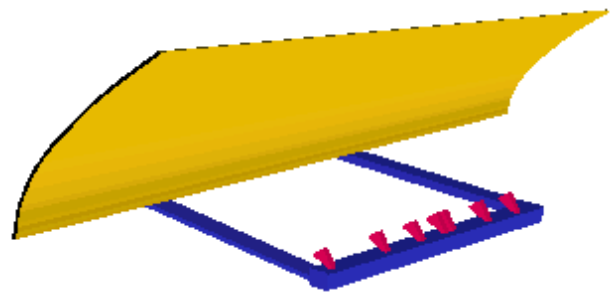

Fig. 1. Artist's concept of the 1-D parabolic cylinder reflector. The reflector has a parabolic shape in the short dimension and a flat profile in the long dimension. This type of reflector has a focal line rather than a focal point. Illuminated by multiple feeds, the antenna pattern has a broad beam in the long, crosstrack, direction and a narrow beam in the short, alongtrack direction the pattern in the far field would be a fan beam.

For this array, the ΔT is given by the formula:

$$\Delta T = \frac{T_{sys}}{\sqrt{2B\tau}} \sqrt{N}\, \frac{\pi}{2} \qquad (1)$$

where T_{sys} is the system noise temperature (K)
B is the bandwidth (Hz)
τ is the integration time (sec)
N is the number of complex visibility terms in the Fourier series
$\pi / 2$ is the 1-bit correlator noise factor.

For a system with T_{sys} = 800 K, B = 200 MHz, τ = 14 seconds with 2x long-track sampling, and N = 246, the ΔT = 0.26 K.

The required power of this system is less than 150 Watts. This assumes 1 mW per correlator, with 1740 1-bit correlators, 0.7 W per radiometers, a data system requiring 20 Watts and a thermal subsystem requiring 50 Watts.

The characteristics of this design are summarized in Table 1.

Radiometric calibration will be provided with a separate Dicke switched radiometer, with noise source injection and using the offset parabolic antenna. The phase calibration between array elements will be done using a phase-switched noise source coupled to the input of each radiometer. The absolute calibration of the data will be done using the frequent over flights of the LEO polar-orbiting microwave radi-ometers operating at the same frequencies (AMSU and ATMS).

Parameter	Value
Operating Frequency	50-60 GHz
Nadir Spatial Resolution	50 km
Swath Width	10,000 km
Altitude	11,000 km
Spacecraft Velocity	1.8 km / sec
Parabolic Antenna Dimensions	1.6 m x 2 m
Number of Radiometers and Feeds	30
Number of Correlators	1740
NEDT per 14 sec sample	< 0.3 K
Total Power	< 150 Watts

Table 1. Characteristics of the MeoSTAR Atmospheric Sounder

III. SUMMARY

The main advantage of this MeoSTAR design is that there is no scanning antenna and no moving parts to disturb the visual and IR sensors on the same satellite platform. Also, with the thinned array of radiometers, and using the latest low power digital circuits, the power requirements for this temperature sounding instrument are estimated to be < 150 Watts. This may even decrease as the state of the art advances.

REFERENCES

[1] Dorian, Terence, A. and Piepmeier, Jeffery R., "Hybrid Synthetic/Real Aperture Antenna for High Resolution Microwave Imaging," Proceedings of the 2003 International Geoscience and Remote Sensing Symposium, Toulouse France, VII: 4368 – 4370, 2003.