EXPERIMENT OF COLLECTIVE PROCESSING CORRELATOR FOR THINNED ARRAY IMAGING RADIOMETER BY THREE ANTENNA INTERFEROMETER

Koji Komiyama, Yoshihiko Kato and Takashi Iwasaki
Electrotechnical Lab. AIST MITI
Light and Radio waves section
1-1-4, Umezono, Tsukuba-shi, Ibaraki Japan 305

Introduction

Satellite microwave radiometers are presently used for remote sensing of the earth. However, the spatial resolution is poor because of the limited aperture of the receiving antenna. In particular, there is no practical passive microwave sensor available in longest wavelength microwave region, though a L band (1.4 GHz) radiometer was used in Sky-lab project to evaluate the possibility of sensing soil moisture and salinity of sea water by scanless mode. Recently, a concept of electrically scanned thinned array radiometer was proposed and the possibility of imaging in L band was shown by an airborne test system. [1] The merit of the thinned array is that it is less massive and lighter than full aperture antenna of the same spatial resolution. However, it needs sophisticated signal processing circuit, that is, mainly numerous correlators used to obtain samples of visibility function of interferometers with different baseline lengths.

In the paper, a signal processing array is proposed for the microwave passive imaging based on the thinned array to reduce the numerousness of correlators in the system of assembled conventional interferometers.

Thinned array

Interferometric radiometer of thinned array shown in Fig.1 has two dimensional resolution along and across the track of satellite by different schemes. The antenna elements are physically long enough to have narrow beamwidth for fine resolution along the track and slim across the track for the beamwidth to cover the swath:that is, the footprint of the antenna beam is a strip on terrain as shown in Fig.1. Every combination of two antenna elements forms an interferometer and the position of all antennas are designed so that the combinations of two antennas may compose interferometers of different baseline lengths as integral multiples of the unit length: it is the minimum among the interspaces between two antennas side by side. Every combination of two antennas needs a correlator as a conventional interferometer to make a sampled value of complex visibility function across the track. Outputs of the interferometers of different baseline length constitute sampled visibility function to crosstrack. The footprint of the antenna beam is divided into finer resolution cells across the track after Fourier transformation of the sampled visibility function. As a whole, signal processor must be equipped with many correlators and signal dividers for measurement of sufficiently sampled visibility function for the cross-track interferometry. The number of components increases exponentially along with the number of antennas.

Collective processing of correlations

Collective processing interferometric radiometer is a kind of signal processing array as shown in Fig.2. The band limited noise-like signals from antennas of thinned array are frequency-shifted by coherent local signals of multiple frequencies and distributed on a spectrum after combining through a multiple input combiner. The values of frequency shifts of antenna signals are decided so that the ratio of frequency intervals between any two

antenna signals on the spectrum may agree with that of the interspace of the corresponding antennas. As the frequency difference between two antenna signals is proportional to the interval between these antennas, cross-correlation signal of differently spaced antenna pair is located in the different position on the spectrum. Resultantly, the cross-correlations made by square detection of combined antenna signals are distributed separately at the frequencies proportional to the interspaces of the antennas. When there are two or more pairs of antennas of equal interval, their cross-correlations overlay on the same frequency. However, if the coherency of the signal processing is retained by using coherent local signals of multiple frequency, the cross-correlations are added in phase as the addition of redundant data.

After the square detection, the correlation signals are separated through filter bank into each quadrature detector where the baseband signal of the complex cross-correlation is made by the coherent reference signal of the same frequency as that of the input cross-correlation signal. Since all local signals for heterodyn converters and all reference signals to quadrature detectors must be coherent altogether, they are generated from coherent oscillators connected to a reference generator.

Experiment

Frequency design of the test set of three antenna interferometric radiometer with the collective processing correlator is shown in fig.3. The center frequency and the bandwidth of antenna signals are 10GHz and 50MHz, respectively. The three antennas are aligned with the intervals of 7.8cm and 15.6cm, that is, the ratio is 1:2. Then, the local frequencies are set so that the ratio of the frequency differences is also 1:2. The frequency-converted and combined antenna signals are distributed at the frequencies of 200, 250 and 350MHz as shown in Fig.3(B). After collective processing, cross-correlations are made and distributed with equal interval of 50MHz on the spectrum. These correlations accompany residual random signals that are caused by randomness of the band-limited noise and cause to the ambiguity of the measurement of the visibility function. The frequency location on IF are designed so that both of the leakage of the input signal and the image signals generated after the square detection may not overlay upon the cross-correlations.

A part of the test set of the three antenna interferometric radiometer is replaced with digital processor which is shown by the enclosure of dashed line in Fig.2. Furthermore, three independent signal generators are adopted for local signal sources of heterodyne converters, because there is no redundant cross-correlations overlaying at a frequency as shown in Fig.3(C). However, as the reference signals at quadrature detectors must be coherent to the input cross-correlation signals, these reference signals of 50, 100 and 150MHz are made by mixing of three local frequencies. A digital oscilloscope of 400MHz sampling capability is used to convert the cross-correlation output of the square detector and the mixed reference signal into two digital data sequences. The data sequences are analyzed and processed by digital processing of Fourier transform and filtering. Two sets of spectral lines of Cross-correlation and references are separately picked out and multiplications between them make complex cross-correlation data as a sampled visibility function.

Image retrieval capability is examined by the experiment of gathering cross-correlations and processing them into the image of a point noise source located 2m far in front of the 3 antenna array. Images are shown in 5 cases of the noise source direction of 0, ± 4, ± 9 degree in Fig.4. Though the resolution of the test set is poor, the positions of the image peaks agree with the angles above. The dual-peaked shapes to $\pm 9^{\circ}$ are caused by grating lobes due to the wide basis of antenna interspace.

Conclusions

Concept of the collective processing correlator for thinned array radiometer for the remote

sensing of the earth is examined. It is promising for large scale interferometric radiometer of real antennas to save RF signal processing components. The experiment of three antenna set shows the capability of imaging noise-like signal source.

References

[1]D. M. LeVine,M. Kao, A. B. Tanner, C. T. Swift and A. Griffis,"Initial Results in the Development of a Synthetic Aperture Radiometer" IEEE Trans. on GRS, Vol.28, No.4, Jul. 1990, pp.614-619.

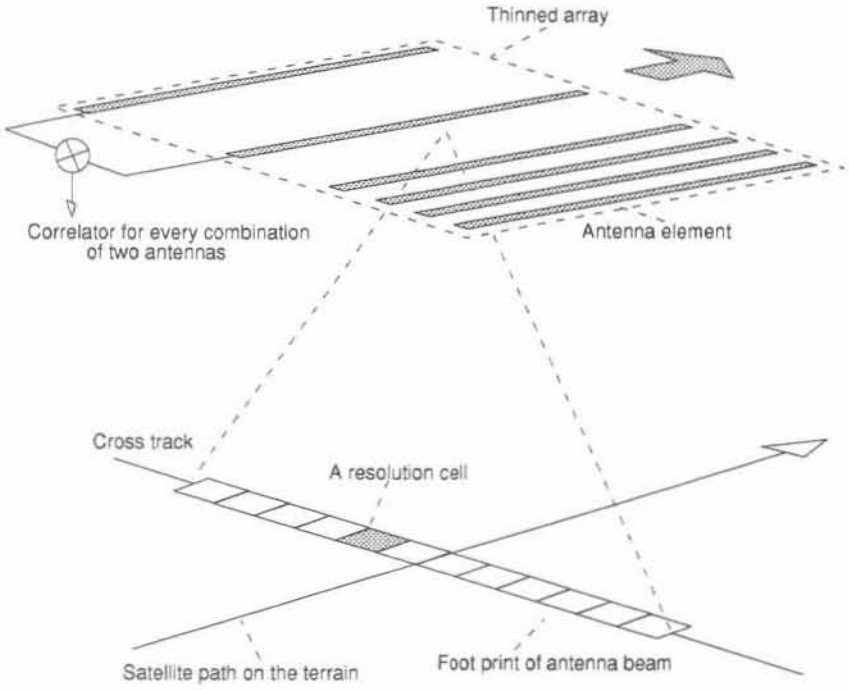

Fig.1 Interferometric radiometer of thinned array

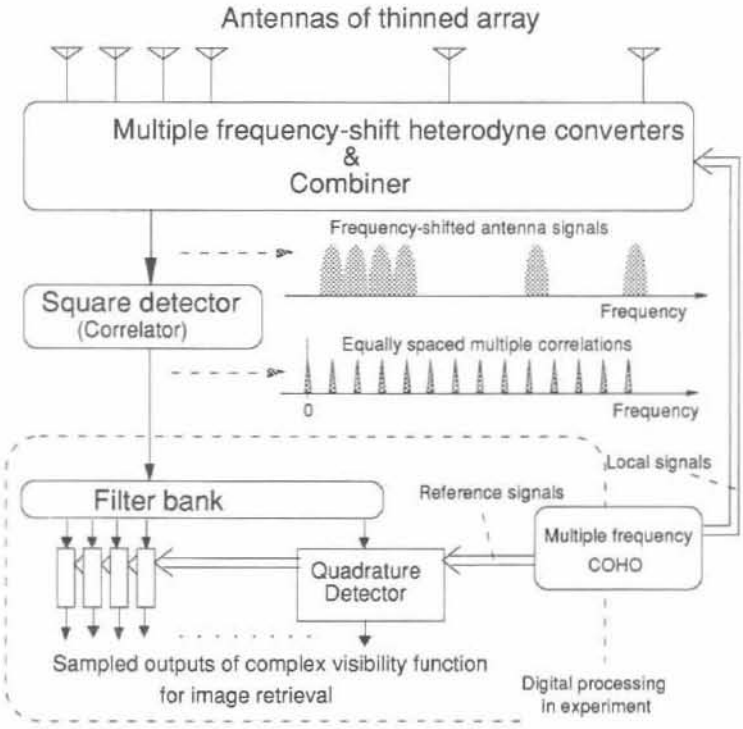

Fig.2 Scheme of collective processing correlator attached to thinned array

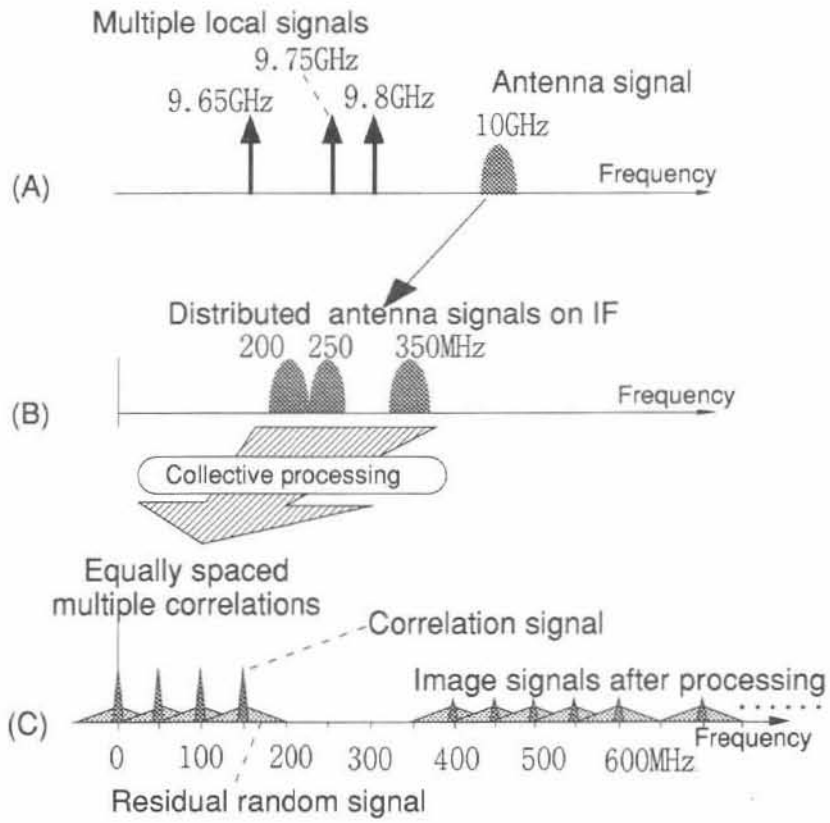

Fig.3 Conceptual design of signal processing for collective processing correlator
(A)Spectra of multiple frequency-shift heterodyne
(B)Distributed antenna signals on IF
(C)Spectrum of cross-correlations made by a square detector

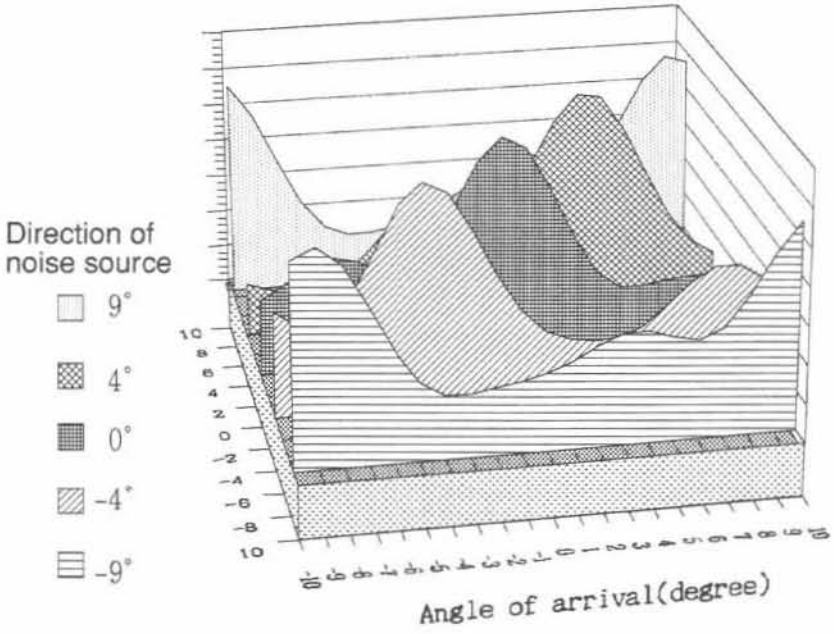

Fig.4 Retrieved images of a point source located in front of three antenna thinned array with collective processing of correlation
Four images are different with respect to noise source direction.