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Adaptive Array for Elimination of Multipath Interference at H.F.

Dr. Peder M. Hansen
Naval Ocean Systems Center
Code 8112
San Diego, California, USA, 92152

A four element adapative array for use in the high frequency (HF) band (3-30 MHz) has been constructed and tested on the air. Multipath interference is a constant problem at HF due to the multiplicity of modes present for a given path. The adaptive array can eliminate multipath interference by adapting to a chosen mode and nulling all others. In order to do this the array must be able to resolve the modes by use of the transmitted reference signal. Theoretical studies indicate that adequate resolution will be provided by a reference signal with bandwidth equal or greater than the inverse of the differential delay between the modes.

The array system was tested on a 230 km over ocean path with the antennas configured such that groundwave and skywave modes were nearly equal. Test results will be shown indicating that the array worked extremely well for elimination of multipath interference.

The array system constructed used a biphase modulated tone as the reference signal and had selectable bandwidths of 3 and 6 KHz. For the test geometry, both these bandwidths were demonstrated to be adequate. A technique allowing voice information to share bandwidth with this reference signal was tested and will be discussed.

In addition, it was discovered that the array can provide signal enhancement effects by following the polarization of the desired mode, given the required degrees of freedom. The theoretical improvement from this effect for skywave propagation is shown to exceed 20 dB.

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SOME CRITERIA FOR THE APPLICATION OF MULTIPLE WAVELENGTH APERTURE SYNTHESIS

ERWIN SCHANDA

Institute of Applied Physics, University of Berne
Sidlerstrasse 5, CH-3012 Berne, Switzerland

The principle of Multiple Wavelength Aperture Synthesis (MWAS) has been proposed by the author [1] for space-borne passive microwave remote sensing systems to observe the earth with high ground resolution. A two-element interferometer can be used simultaneously at a number of sufficiently separated frequencies to yield a number of spatial Fourier-components of the observed scenery for synthezising a high resolution one-dimensional "image". This arrangement could become particularly useful in space-borne earth observations, e.g., on board of the Shuttle where constraints in observing time (satellite speed is usually appr. 7 km/sec), or in room for housing more complex structures are drastically limiting the possibilities of high resolution imaging of the ground by microwave radiometry. But the advantage of having a large number of spatial Fourier-components simultaneously available is attractive also for other applications, e.g., in the field of radio-astronomy for the study of celestrial objects which are rapidly changing the character of their emission. In most of these applications a two-dimensional imaging is desired; this can be accomplished by using a set of three antennas in an orthogonal arrangement leading to a two-dimensional Fourier procedure.

The antenna temperature T_a of a correlation interferometer is a function of the element separation measured in numbers of wavelengths u and v in the x and y directions respectively. For constant geometric separation the use of different wavelengths yields different spatial Fourier-components of the antenna temperature T_a (u,v) due to a given scene, i.e., due to a given brightness temperature T_b (l,m) as a function of the directional cosines l,m. The antenna temperature T_a (u,v) and the brightness temperature of the scene T_b (l,m) are Fourier transforms of each other [2], in particular,

$$T_a(u,v) = \iint_{-\infty}^{\infty} T_b(l,m)\,|A(l,m)|\,\exp[2\pi i(ul+vm)]\,\lambda^{-2}(1-l^2-m^2)^{-\frac{1}{2}}\,dl\,dm$$

where λ is the wavelength, and A (l,m) = $A_{max} \cdot g(l,m)$, the effective area of the interferometer is determined by the maximum interferometer area (in the main direction), and the normalized gain function of the interferometer, with the infinitesimal solid angle $d\Omega = dl dm(1-l^2-m^2)^{-1/2}$, and $ul+vm = \nu_0 \tau$ center-frequency times the relative wave delay between the antennas of a pair.

Keeping A_{max} constant for all wavelengths would cause the resolved area in the scene to be proportional to λ^2. To avoid an untolerable amount of uncorrelated signals, adjustment of the effective antenna area to $A_{max}/\lambda^2 \approx$ constant for all wavelengths is mandatory. The utilization of a feed horn common to all wavelengths can illuminate a parabolic dish in a kind as demanded for wavelength-adjusted effective antenna areas.

It is obvious from the above Fourier-relation between T_a and T_b that the brightness temperature of the scene has to be independent of wavelength within the used spectral range in order to achieve an aperture synthesis by a multi-frequency receiver equivalent to one by a multi-antenna arrangement. There are situations where this demand for frequency independent brightness temperature is relatively well fulfilled, in astrophysics (e.g., a synchrotron emission before a thermal background) as well as in terrestrial situations (e.g., metallic objects on agricultural soil). There are however many more situations where the brightness temperatures within a scene are mildly - in some situations (where spectral line radiation is involved) even strongly - dependent on frequency. If no a priori knowledge on the spectral behavior of the radiation sources within the observed scene is available, no reliable or even no useful synthesis can be achieved because $T_b(l,m)$ in the above Fourier-integral has additionally an unknown functional dependence on u and v. Investigations on the emissivities of terrestrial natural media have shown that for most media (if not much water is involved) the brightness temperature exhibits a slight increase of 5 % to 15 % over a frequency increase of about one decade in the microwave spectrum. The effect of water (moisture content) on the brightness temperature is very characteristic, and it seems it can be taken into account approximately as an a priori information in the processing of the synthesis. Also in astrophysics applications specific emission mechanisms can be assumed for the frequency dependence.

The effect of the spectral behavior of brightness temperatures on the feasibility of MWAS, the compensation and incorporation of this effect into the processing will be discussed. Several model situations with relevance to astrophysics and earth-sciences will be considered.

References:

[1] SCHANDA, E., "High ground resolution in passive microwave earth observations from space by multiple-wavelength aperture synthesis", 27th Congress Internat.Astronaut.Fed., Anaheim/California, Oct.10-16, 1976, Paper No. IAF-76-057.

[2] CHRISTIANSEN, W.N., HOEGBOM, J.A., "Radio Telescopes", Cambridge University Press, Cambridge / U.K., 1969.