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CHANNEL CHARACTERIZATION FOR A SATELLITE AIR TRAFFIC CONTROL SYSTEM

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Recently considerable controversy has developed on an international scale regarding the establishment of a satellite communication/navigation system for transoceanic air traffic control. Although the considerations bearing on the selection of such a system must necessarily involve more than technology alone, an important technical factor is the characterization of the propagation channel. If narrow beam, high gain aircraft antennas were available for application in the space service, the propagation channel might be modeled as line-of-sight transmission through a turbulent medium. However, because of structural limitations imposed by the airframe and beam steering problems associated with high gain antennas, aircraft antennas employed in any satellite communication/navigation system for transoceanic air traffic control would most likely be broad beam. The inadvertent illumination of the rough ocean surface in the proximity of the aircraft by such a broad beam antenna will result in a propagation channel characterized by multipath.

Significant advances have been made over the past few years in the scattering of electromagnetic waves from rough surfaces such as the sea[1,2,4]. The geometric parameters necessary for employing these results can be derived from a spherical coordinate system with the polar axis running through the aircraft and the longitudinal plane of reference defined by the geocenter, the aircraft, and the satellite. By considering elemental areas of the spherical surface as locally plane the previously noted rough surface studies find direct application and the total power scattered by the sea surface can be found by integration over the colatitude θ and relative longitude ℓ_r associated with each elemental area. To effect this integration the variation of the local grazing angles (ψ and χ) and the angle between the planes of incidence and reflection (ϕ) must be found as a function of θ and ℓ_r. An example of this variation is shown in Table I for an aircraft at a height of 40,000 feet and an earth synchronous satellite when the aircraft is at latitude 45° and longitude 0°, relative to the satellite. Also shown in Table I is the path differential between the direct ray and the rough earth reflected ray expressed in kilometers (ΔR) and in microseconds ($\Delta\tau$). Although not evident from this Table, the angle ψ is relatively constant whereas the angle χ changes rapidly as a function of the colatitude θ.

The rough surface of the sea is modeled as a composite rough random surface exhibiting two independent scales of roughness. The larger scale (lg-sc) of roughness having dimensions significantly larger than a wavelength can be treated in the Kirchhoff approximation[5]; the smaller scale (sm-sc) of roughness having dimensions much smaller than a wavelength can be treated by the method of perturbations[4]. To a first approximation the power scattered by such a composite rough surface may be considered as the sum of the powers scattered by each surface independently[1,4]. The geometrical parameters of the previous example have been

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employed in conjunction with composite rough surface scattering theory to determine, for every point of the mean sea surface mutually visible from the aircraft and the satellite, the power scattered per unit sea surface area. Contours of equal received scattered power per unit of sea surface area are shown in Figure 1 along with the additional parameters relevant to the calculations. For these parameters the total power scattered by the sea surface between isotropic antennas of vertical polarization is 11.3 dB above the power propagated by direct line-of-sight, with more than 99% of the sea scattered power coming from within the sea surface bounded by 1.0° colatitude.

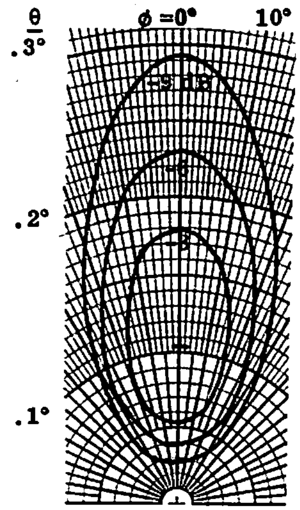
The resultant signal propagated between the aircraft and the satellite is composed of a steady component due to direct line-of-sight propagation and scattered component due to scattering from the rough surface of the sea. On the basis of a ray representation the sea scattered component arises as a result of reflections from a large number of favorably oriented reflecting facets on the sea surface. The resultant signal is then composed of a steady and a gaussian component and may be expected to follow the Rice-Nakegami distribution.

The transmission of information by means of a modulated carrier requires that any channel characterization also consider fluctuations of the signal in time and frequency. A general representation[3] of these fluctuation is afforded by the Delay-Doppler Scatter Function $S(\tau, f)$. For the previous example, the sea scattered power exhibits a 3 dB multipath spread of about 3 μ-sec; the Doppler spread cannot be so easily characterized as it depends not only upon Doppler effects related to aircraft motion, but also those induced by motion of the sea surface[4].

1. D.E. Barrick and W.H. Peake, Radio Sci, 3, pp 865-68, 1968.
2. F.G. Bass et al, IEEE Trans Ant Prop, AP-16, pp 554-68, 1968.
3. P.A. Bello, IEEE Trans Comm Sys, CS-11, pp 360-93, 1963.
4. I.M. Fuks, Izv VUZ (Radiofiz), 9, pp 876-87, 1966.
5. B.I. Semenov, Radiotekh i Elek, 10, pp 1666-73, 1965.

Table I: Geometry (θ= 0.1°)

ℓ_r	χ	ψ	ϕ	ΔR (km)	$\Delta\tau$ (μ-sec)
0.0	48.5	36.9	180.0	15.2	50.8
10.0	48.5	36.9	170.0	15.3	51.3
20.0	48.5	36.8	160.0	15.8	52.6
30.0	48.5	36.8	150.0	16.4	54.8
40.0	48.5	36.8	140.0	17.3	57.8
50.0	48.5	36.8	130.0	18.4	61.5
60.0	48.5	36.8	120.0	19.7	65.7
70.0	48.5	36.8	110.0	21.1	70.5
80.0	48.5	36.8	100.0	22.6	75.5
90.0	48.5	36.7	89.9	24.2	80.7
100.0	48.5	36.7	79.9	25.7	85.8
110.0	48.5	36.7	69.9	27.2	90.9
120.0	48.5	36.7	59.9	28.6	95.6
130.0	48.5	36.7	49.9	29.9	99.8
140.0	48.5	36.7	39.9	31.0	103.5
150.0	48.5	36.6	29.9	31.9	106.5
160.0	48.5	36.6	19.9	32.6	108.7
170.0	48.5	36.6	9.9	33.0	110.0
180.0	48.5	36.6	0.0	33.1	110.5



f = 1660 GHz
σ= 4.0 mho/m
ε= 80.0

$\frac{L}{\lambda}$ = 0.1 (sm-sc)

$\frac{L}{h}$ = 10.0 (sm-sc)

$\frac{L}{h}$ = 10.0 (lg-sc)

antennas: isotropic

polarization: vertical

L = correl dist h = rms roughness

+ = specular reflection point

Fig 1: Contours of Equal Received Scattered Power per unit Area of Sea Surface