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HELICOPTER BLADE MODULATION MODEL (REVISED).(U)
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HELICOPTER BLADE MODULATION MODEL (REVISED)*

MRI Report 149-16

29 March 1978

R. L. Mitchell

Two basic helicopter blade modulation models were described in Reference 1. One was based on scattering from the blade tips and the other was based on the specular flash. Evidence presented in Reference 2 supports the latter model. We will rederive the model here.

Let us assume that scattering from the blade of length L acts as if the blade were a thin wire, so that the reflected voltage pattern as a function of ϕ, the angle measured from the blade axis, will be approximately

$$v(\phi) = \mathrm{sinc}[2(L/\lambda)\cos\phi] \tag{1}$$

where $\mathrm{sinc}(x) = (\sin\pi x)/\pi x$. If α is the angle between the line of sight and the plane of rotation, we can write

$$\cos\phi = \cos\alpha \cos\beta \tag{2}$$

where β is the angle of the blade within the plane of rotation measured from a point closest to the radar. We can set

$$\beta(t) = 2\pi f_s t + \theta \tag{3}$$

where f_s is the blade rotation rate and θ is a phase angle. Substituting (2) and (3) into (1) we obtain

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*This report is a revision of MRI Report 149-12, a report of the same title. The author acknowledges D. A. McPherson for pointing out the missing phase modulation term in the earlier report.

[1] Mitchell, R.L., and I.P. Bottlik, "Techniques for Simulating Realistic RF Environment Signals on the RFSS," MRI Report 131-25, 28 February 1977.

[2] "Improved Hawk Systems Threat Definition & Capabilities Against Helicopter & Liaison Aircraft," Raytheon Final Report BR-6501, Revision B, 15 January 1975.

the amplitude modulation term

$$v(t) = \mathrm{sinc}[2(L\cos\alpha/\lambda)\cos(2\pi f_s t+\theta)] \tag{4}$$

In addition, there is a phase modulation term due to the blade rotation. If we assume that the phase center is at the center of the blade, the combined amplitude and phase modulation is given by

$$v(t) = \mathrm{sinc}[2(L\cos\alpha/\lambda)\cos(2\pi f_s t+ \theta)] \cdot e^{j2\pi(L\cos\alpha/\lambda)\cos(2\pi f_s t+\theta)} \tag{5}$$

For N blades that are equally spaced, we can write

$$v(t) = \sum_{n=0}^{N-1} \mathrm{sinc}[2(L\cos\alpha/\lambda)\cos 2\pi(f_s t+n/N)] \cdot e^{j2\pi(L\cos\alpha/\lambda)\cos 2\pi(f_s t+n/N)} \tag{6}$$

In practice, the front and back edges of the blade might scatter with different radar cross sections, and the blade might be shadowed during a portion of the cycle. Therefore, let us define another amplitude term $A(\phi)$ to account for this variation in RCS, so that (6) now can be written as

$$v(t) = \sum_{n=0}^{N-1} A(\phi_n)\, \mathrm{sinc}[2(L\cos\alpha/\lambda)\cos\phi_n] \; e^{j2\pi(L\cos\alpha/\lambda)\cos\phi_n} \tag{7}$$

where

$$\phi_n = 2\pi(f_s t+n/N) \tag{8}$$

Some computation time savings can be gained by constraining the ratio f_r/f_s to be an integer (not a serious limitation) where f_r is the sample rate (or the PRF). If we define

$$M = f_r/f_s \tag{9}$$

then sampling (7) at $k\Delta t$ where $\Delta t = 1/f_r$, we can write the phase term in (8) as

$$\phi_n = 2\pi(kf_s\Delta t+n/N) = 2\pi \frac{kN+nM}{MN} \tag{10}$$

We need a table of size MN to completely define the phase function (generally $M \leq 60$ and $N \leq 5$ so that $MN \leq 300$). Although L and λ are fixed, α will be a real-time variable in (7) so that sinc and phase calculations must be performed in real time (table-lookup schemes should provide adequate accuracy).

Equation (7) can barely be implemented on the Datacraft computer. It is estimated that for N=2 the samples can be computed at a 10-12 kHz rate for both the main and tail rotors (provided the computer is dedicated to the computation). For larger blade numbers, or if the Datacraft must be shared, it is expedient to use the AP120B for the calculation of (7).