SOME ASPECTS OF ACTIVE ARRAY ANTENNA SYSTEM DESIGN FOR SATELLITE APPLICATIONS

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Recently, there has been considerable interest [1] in the technological development of fixed and scanning beam spot satellite antennas. Two possible configurations for the 30/20 GHz satellite system are shown in Figure 1. Specifically, Figure 1a shows the Multiple Fixed Spot Beam Antenna System and the Multiple Scanning Spot Beam Antenna System is displayed in Figure 1b. Both of these systems have the common feature that they employ monolithic microwave integrated circuit (MMIC) devices for active apertures. There are a number of distinct advantages to using the MMIC modules in the spacecraft antenna systems. A few of the important ones are: (a) electronic beam steering; (b) dynamic control of reflector illumination as a function of scan angle; (c) fast and power-conservative switching with FET; (d) solid state power amplifiers with distributed amplification; (e) phase and amplitude weightings for optimum performance; and, (f) reliability through graceful degradation. It is anticipated that, in order to effectively control the illumination and to provide the sufficiently high power needed to operate in a geostationary orbit, it may be necessary to employ arrays with a rather large number of radiating elements, on the order of 100 to 1000. Two important problems must be addressed before such an array can be built. The first of these is the accurate characterization of the MMIC in the array environment where dynamic phase and amplitude control will be implemented. The second is to estimate the crosstalk noise, coupling and pulse distortion in the multiconductor lines carrying the logic signals from the command computer to the MMIC modules. In this paper, we examine both of these aspects of the active satellite antenna array design.

Let us first turn our attention to the MMIC packaging problem. The schematics of the MMIC package are shown in Figure 2. We discuss in this paper a number of different configurations for the transitions shown in Figure 2 and compare their relative advantages and disadvantages. Next, we consider the problem of estimating the crosstalk noise and signal distortion introduced by the proximity effects in multiconductor transmission lines that carry the control signals from the command computer to the MMIC chip. If the level of crosstalk or the distortion in the signal is too high, it is possible for false gating to occur and this could, in turn, result in error in the beam pointing or scanning of the satellite antenna. Thus, it becomes important to consider the problem of determining the level and the degree of the distortion of digital pulses used to alter the amplitude and phase distortions of the array.

The estimation of the signal distortion and coupling requires two key steps. The first of these is to compute the Maxwell's capacitance matrix and the inductance matrix of the coupled lines. To evaluate these matrices, it is necessary, as a first step, to determine the charge and current distributions on the coupled microstrip lines under different excitation conditions. The problem of determining these distributions can be cast into one of solving appropriate integral equations for the unknown charge or the current on the coupled strips. Conventional methods, such as the method of moments, are not too suitable for the problem at hand because the number of unknowns to be solved for is rather large. Instead, we employ an efficient iterative technique that is numerically more efficient and requires much less storage than the matrix methods. After examining a number of alternatives, it was determined that the spectral iterative technique applied in conjunction with the minimization in the boundary condition error (BCE) [2], [3] is best suited for generating an iterative solution with guaranteed convergence. The convergence is assured because for each subsequent iteration the BCE can be shown to decrease monotonically. The iteration procedure is carried out most efficiently by employing the spectral domain approach in which the discrete convolution is evaluated with the aid of the Fast Fourier Transform.

The accuracy of the solution can be systematically improved by increasing the number of iterations; no elaborate search for a set of basis functions is required as in the Galerkin procedure.

Next, modal analysis can be performed to compute the eigenvalues of the coupled system. These, in turn, can be employed to determine the propagation characteristics of the coupled lines. Once the eigenvalues of the system are known, it becomes possible to formulate the problem of computing the time-domain response of the multiply coupled lines terminated with non-linear loads, e.g., logic gates, whose V-I characteristics are presumed known. A set of non-linear, coupled matrix differential equations is obtained for the transmission line voltages and these equations are then solved by time stepping [4]. Numerical calculations have been compared with experimental measurements and good agreement has been found. Illustrative results are included in the paper.

References

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[4] S. Castillo and R. Mittra, "Analysis of N-conductor transmission line system terminated with non-linear digital devices," to appear.

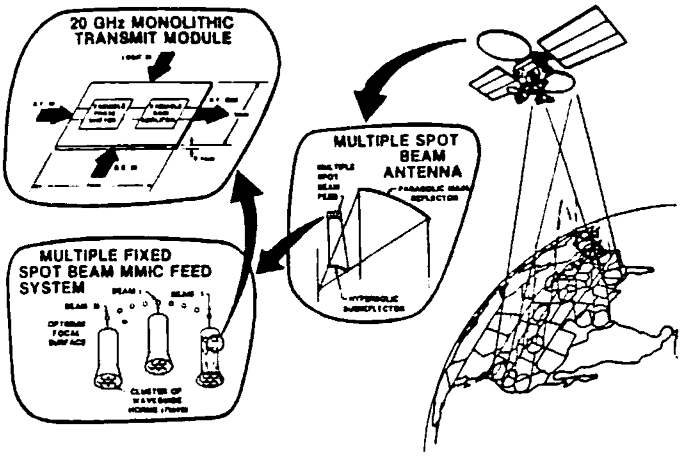


Figure 1a. Multiple fixed spot beam antenna system.

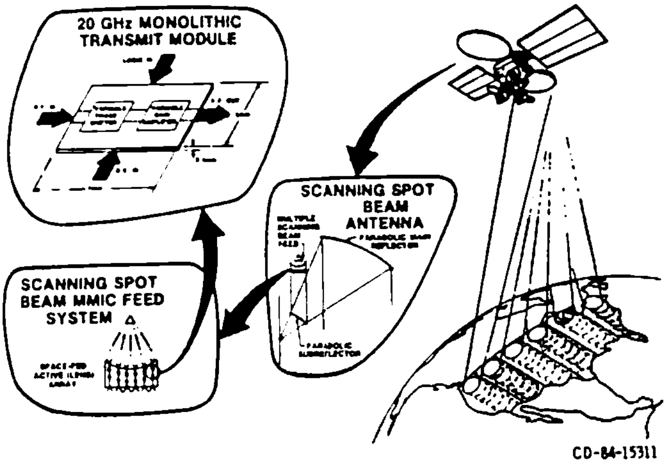
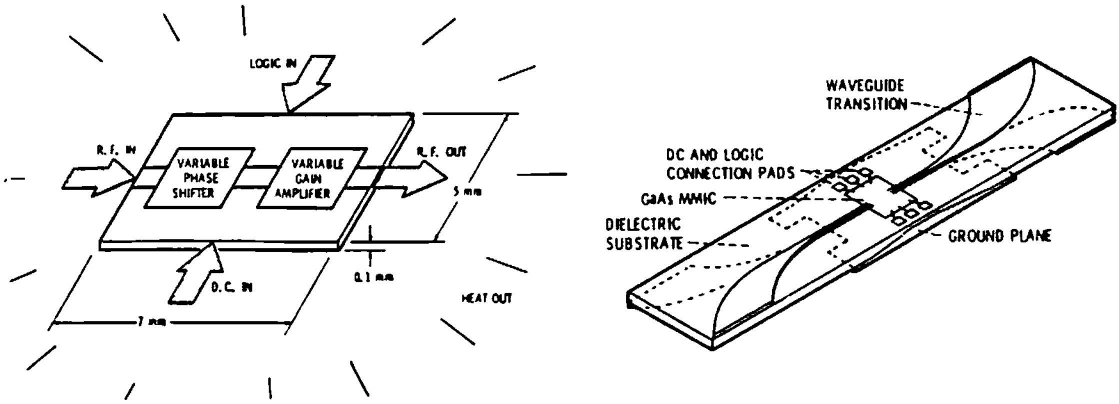


Figure 1b. Multiple scanning spot beam antenna system.



(a) MMIC interconnectivity.
(b) Typical packaging configuration.

Figure 2. Schematics of the MMIC package.

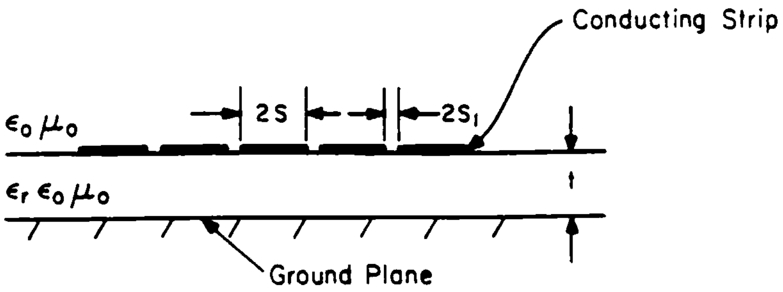


Figure 3. Geometry of multiconductor microstrip lines.

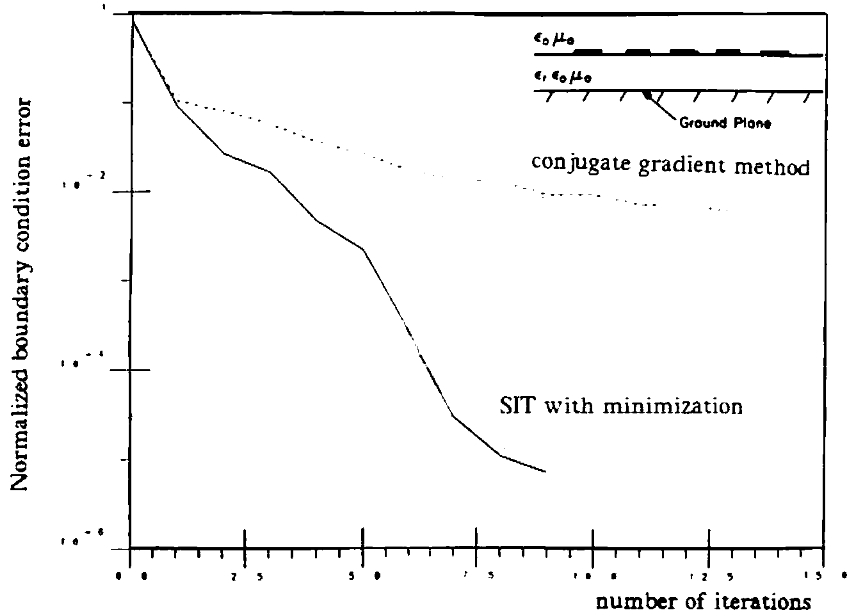


Figure 4. Normalized boundary condition error against number of iterations.

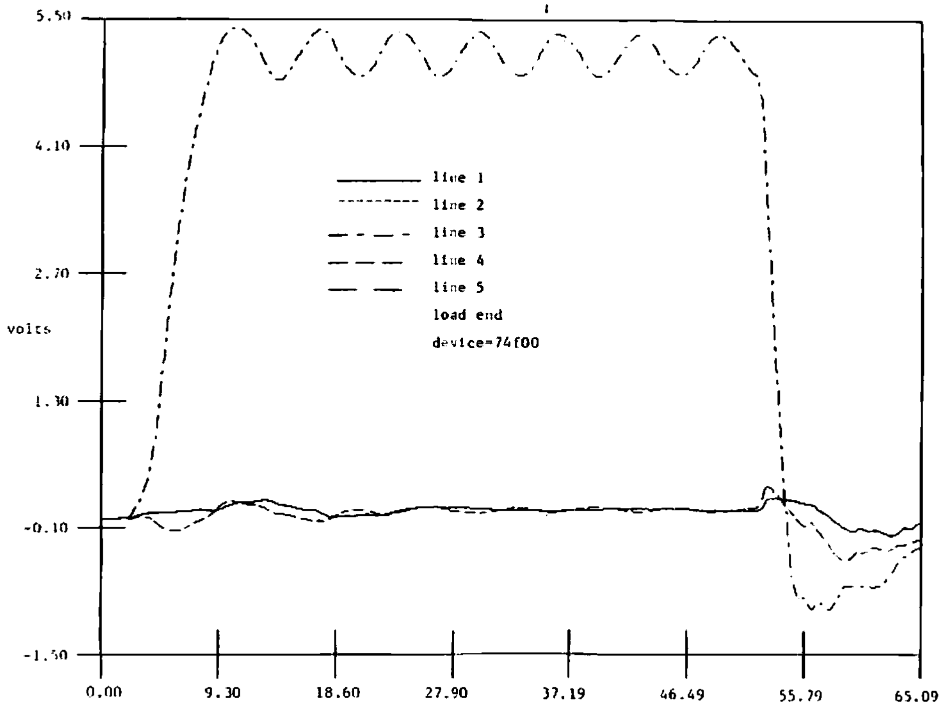


Figure 5. Crosstalk in a five line system.