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Phase Interpolation Circuits Using Frequency Multiplication for Phased Arrays

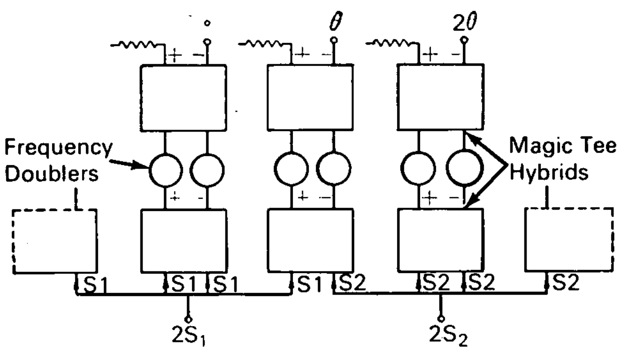

Figure 1A. Phase Interpolation Using Frequency Doublers and Magic Tee Hybrids

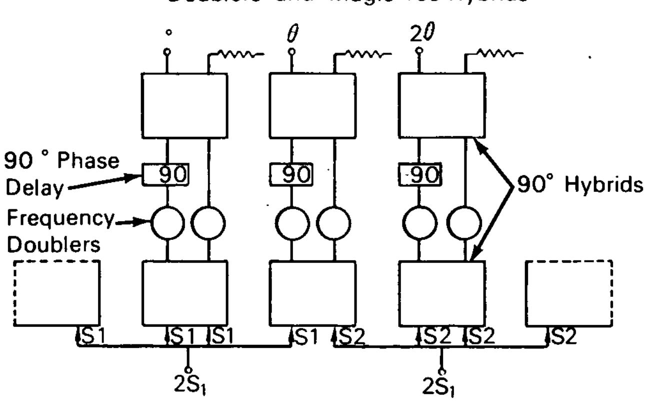

Figure 1B. Phase Interpolation Using Frequency Doublers and 90° Hybrids

The problem:

A phased array antenna system with many elements requires an array feed system to provide phase control. Prior systems have used techniques ranging in complexity from a simple phase shifter at each element to the use of a sophisticated intermediate frequency method requiring only one phase shifter to scan the beam. The advantages of prior intermediate frequency systems have been offset by disadvantages such as: (a) accumulation of phase shift errors which is undesirable for large arrays; (b) inherent complexity which increases the manufacturing cost.

The solution:

A precise phasing circuit was designed, based upon a phase interpolation concept, which would function with such systems as "Huggins Scan" or with nearly any other phasing system.

How it's done:

A fundamental understanding of the proposed design scheme can be achieved by considering a linear array which is phased by an intermediate frequency phase device. Since these devices are quite expensive to construct, it is desirable to provide electronic circuitry which will enable the device to scan additional antennas. Since the phases are accurately known, it is possible to produce an extra set of phased outputs of the original phasing device. Each phase line is then said to be interpolated between adjacent phases of the original phasing device. Two variations of the phase interpolation circuit are shown in Figure 1.

A generalization of this design scheme produces not merely a single signal with a phase halfway between two other phases, but one which splits the interval into N intervals.

To trace the interpolated signal, consider the two adjacent signals $S_1 = \cos \omega t$ and $S_2 = \cos (\omega t + \Theta)$. (Hereafter the notation $S_1 = \omega/\underline{\Theta}$ and $S_2 = \omega/\underline{\Theta}$ will be used interchangeably with the above.) At the sum and difference ports, respectively, of the 180° hybrid shown in the center of Figure 1A, the signals are $\sqrt{\frac{1}{2}}(S_1 + S_2)$ and $\sqrt{\frac{1}{2}}(S_1 - S_2)$. If the doublers are ideal, then the respective doubler outputs are proportional to $1/2(S_1 + S_2)^2$ and $1/2(S_1 - S_2)^2$. The difference

(continued overleaf)

term at the output magic tee is $\sqrt{2}\, S_1 S_2$. The corresponding signal at frequency 2ω is $\frac{1}{\sqrt{2}} \cos(2\omega t + \Theta)$. The same processes are repeated to derive the outputs at the left and right of this one. These signals are: $\frac{1}{\sqrt{2}} \cos(2\omega t)$ and $\frac{1}{\sqrt{2}} \cos(2\omega t + 2\Theta)$. Thus, it can be seen that the circuit of Figure 1A does provide three output signals of which one has a phase angle midway between those of the other two. In the doubler case, the frequency and phase difference between the control signals are both doubled. If this process is repeated for each of M elements of a phasing device, the new device will phase (2M-1) elements. It should also be clear that the procedure may be performed a second time in principle and so phase an array of 4M-3 elements, etc. The circuit of Figure 1B performs the same function but uses 90° hybrids instead of the 180° hybrids of Figure 1A.

The system does have distinct advantages as compared with the straightforward way of increasing the number of phased elements. Its main advantages are due to the repetition of these circuits for each element in the array, the relative simplicity of the circuits, and the accuracy of the phase interpolation. When used in conjunction with a harmonic generation scheme, it may be much cheaper and simpler to build a phasing device with only a fraction of the number of phased output signals needed for the final array. The number of phased output signals needed for the final array could be increased by using one or several stages of phase interpolation.

Note:

Requests for further information may be directed to:

Technology Utilization Officer
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National Aeronautics
and Space Administration
Washington, D.C. 20546
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Patent status:

Inquiries about obtaining rights for the commercial use of this invention may be made to NASA, Code GP, Washington, D.C. 20546.

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