layer of ionized atmosphere called the ionosphere or the Heaviside layer, which in fact does reflect such low frequency signals back to earth. It is not a very efficient reflector. It varies in its efficiency between day and night, and with the season, and also with the sun spot activity which goes through an eleven-year cycle. The result is that it is a rather variable means of transmission. It is worldwide in that everything shot up there comes down again somewhere, and there is a great demand for h.f. radio channels because until about five years ago there was no other means of getting very long-distance communications, especially over oceans. As a result the radio spectrum in the h.f. region is terribly congested; in fact if you had a receiver that covered that band and just tuned across it you would be very lucky if you found at any time even one empty space out of hundreds. There should be some spaces because all these transmissions are licensed and controlled, but there are a number of pirates.

Another point is that the ionosphere is an inefficient reflector in the same way as the moon is an inefficient reflector. There is a bandwidth limitation on h.f. radio systems which may restrict them to perhaps two telephone channels or half-a-dozen telegraph channels, which is nothing like enough for the demands of the future. In fact when submarine cables with built-in submerged repeaters came into use three or four years ago they constituted a tremendous advance and those across the North Atlantic carry practically all the traffic now. The h.f. radio is still there, but is only used as a back-up, and I do not think that anyone really wants to go back to it if they can avoid it.

Mr. E. C. Clear Hill (*De Havilland Aircraft Co. Ltd.*): As I understand it, the Ariel satellite has recently become of depleted value because of the recent American experiments. The problem of radiation which could perhaps be introduced by a potential enemy, and the disruption of worldwide communications which might rely heavily on this type of device in the future—does this in fact represent a very real danger? Insurance of alternatives, perhaps at different levels—are these matters being considered?

Mr. K. W. Pearson: It is quite a real danger. In addition, of course, to the American-produced ionized particles, or whatever you like to call them, which have caused trouble to Ariel, there are natural belts of radiation around the earth which are known as the Van Allen belts. Not very much is known about them. They have a name and that is about all. It is believed that the high-energy particles, protons and electrons in these belts can in fact cause deterioration not only to solar cells which are exposed, of course, to radiation, but also to the various solid-state components in satellites. Telstar and Relay, which I mentioned, are both somewhat deliberately designed to travel through the Van Allen belts, and they carry in addition to the solar cells which are to power the communications system on board, a number of other solar cells which are merely there to check this effect. This is done by shielding them with various thicknesses of material so that one can get an idea of the velocity of the attacking particle in each case, or the distribution of velocities. indicating how many particles of greater than a certain energy are striking the satellite. The solar cells which are actually used to charge the batteries which run the communications system are protected to some extent by a layer of synthetic sapphire which has the property of preventing a large number of these particles from damaging the solar cells, without at the same time significantly reducing their efficiency. It is difficult to know just what will happen in the future. I might just add that all permanent practical satellites will probably be outside the Van Allen belts. I mentioned eight thousand miles. This is well above the centre of the inner Van Allen belt and it is hoped that at that level problems of radiation will be much reduced.

One other point is that although solar energy is at the moment the favourite source of energy for satellites because it is readily available, even at a cost, there are, of course, tremendous advances going on in other means of producing power. Nuclear power, for example, is being considered—in fact one satellite is up using a little nuclear power pack—and this may provide the solution to deterioration of solar cells.

Correspondence

To the Editor,
The Computer Journal.

Dear Sir,

I would like to pass on a few comments on D. C. Handscomb's paper of the computation of latent roots of a Hessenberg matrix by Bairstow's method (*Journal*, July 1962).

I have written a program for a Mercury computer which reduces a general square matrix to Hessenberg form by elementary similarity transformations, but then proceeds by obtaining the characteristic equation. The program then tries to find a quadratic factor using Bairstow's method. In some cases this fails to converge; if in these cases the roots of the quadratic factors are inspected, and if it is found that one has converged (the other corresponding to a pair of complex roots) then Newton's method is used to obtain to the required accuracy the one that has converged. When a root or pair of roots is found it is removed from the equation. In order to try to find the roots in ascending order (Wilkinson has demonstrated the advisability of this in his paper on the "Evaluation of zeros of polynomials" in *Numerische Mathematik*, Vol. 1, pp. 150–80), the initial guess in trying to find any pair of roots has been chosen to correspond to a pair of very small roots.

This program, which has been written in double-precision arithmetic (57 bit floating point) to try to overcome the problem of instability, has been successfully used on a number of matrices, including the one of order 22 quoted by Handscomb. For this it took about four minutes to find the roots once it had been reduced to Hessenberg form (as compared with $12\frac{1}{2}$ minutes for Handscomb's program). It agreed on 19 of the roots exactly with Wilkinson's results (as quoted by Handscomb), and on the other 3 the difference was only one in the last place quoted, i.e. for roots 2, 3 I obtained $0{\cdot}2859394 \pm i0{\cdot}06599475$ (5) and for root 16 I obtained $0{\cdot}0000015735$ (6).

These accuracies and times have been obtained on a number of other matrices of this size, and it would thus appear that for a two-level storage machine such as Mercury, working throughout to double precision and reducing to a characteristic equation will be, in general, both faster and more accurate than Handscomb's method, which keeps to single precision throughout.

Yours faithfully,

J. C. F. Payne.

The General Electric Company Ltd.,
Erith, Kent.
6 November 1962.