

## V MISCELLANEOUS PROBLEMS

### A STUDY OF THE R-F PROPERTIES OF MICROWAVE GENERATORS

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Description of Project The r-f properties of a tunable 10-cm continuous-wave magnetron are being investigated prior to an attempt to operate such tubes in parallel. From the information obtained, the electronic and equivalent circuit characteristics are to be calculated. It is planned to begin a similar study of the properties of velocity-modulation tubes operating in this frequency range when the present work is completed.

Status The continuous-wave tunable magnetrons under test at this time are of the Raytheon Type, 6K-62. Cold tests have been made on two tubes of this design and theoretical studies are being conducted to predict their properties under locked conditions. Experiments will be conducted in the near future on parallel tubes to verify the analytical predictions.

### B ELECTRONIC DIFFERENTIAL ANALYZER

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Description of Project This project is concerned with the design of an electronic differential analyzer. Among the basic arithmetic operations of addition, subtraction, and multiplication, multiplication presents the greatest problem in its realization. Multiplication is essential, however, for all but the simplest computations that one can conceive, and therefore the development of a satisfactory multiplying circuit was chosen as a first preliminary objective.

When a satisfactory multiplying circuit has been completed, attention will be turned to the general problem of building an electronic differential analyzer. Most of the prototypes used for the simulation of various special problems at the present time are d-c devices, employing d-c amplifiers and d-c coupling. They all possess the disadvantages of d-c circuits with respect to stability and drift. This group has felt that many advantages would be gained if a-c coupling and a-c amplifiers could be used.

In the first place it is planned to have the solution repeat at a fairly high rate and to display the result upon an oscilloscope. This automatically converts the problem from one involving direct current to one involving a series of pulses. During a single solution, however, the pulses will contain a d-c component and this poses a problem if a-c circuits are to be used. Two possible methods of solving this problem are evident, and both will be investigated.

The first method is to have the pulses which represent the solution occur at widely spaced intervals of time, so that the circuits will all return to their equilibrium position between the pulses. Then, if their time constants are sufficiently long, the a-c circuits will act like d-c circuits for the duration of the pulses. The second method is to have the pulses occur at more closely spaced intervals of time, and to return the circuits to equilibrium by discharging all the condensers through gas diodes at the end of each solution.

It is thought that the first method may be quite satisfactory, although it effectively utilizes only a small fraction of the time. The reason for this is that the actual time taken for a solution is limited in either case to about 10,000  $\mu$ sec by the low-frequency response of the amplifiers (i e by the time constants). If the solutions were repeated with no pause, they could be displayed upon an ordinary oscilloscope at a repetition rate of about one hundred per second. If a long pause were necessary between solutions, the repetition rate might have to drop to about one per second but it would still be possible to display this result upon a long persistence scope, and no accuracy would be lost in the process.

Status In connection with the problem of multiplication, two types of multiplication have been considered: direct multiplication, and multiplication by using the relation,

$$AB = \frac{(A + B)^2 - (A - B)^2}{4}$$

To date a satisfactory direct multiplying circuit has not been found.

The second type of multiplier requires three adding circuits and two squaring circuits. Two satisfactory adders for use with this type of multiplier have been built and tested. One uses a single pentode stage stabilized by voltage inverse feedback and fed through series resistors. This circuit gives an accuracy of better than 1 per cent for input voltages ranging from 0.01 to 20 volts. The second adder using two pentodes stabilized with current inverse feedback and connected to a common load resistance has proved to give better than 1 per cent accuracy for input voltages from 0.01 to 1 volt.

Two squaring circuits have been tested. One type makes use of the so-called push-push circuit in which the grids of two high transconductance tubes are fed in push-pull (that is 180 degrees out of phase) and the output is taken from the plates connected in parallel. In this manner the direct component is cancelled out and only the squared component remains. This type of squarer has been found to be accurate to within 2 per cent for a two-decade variation of the input voltage, which corresponds to a four-decade variation in the output voltage.

The second squaring circuit makes use of the fact that the current-voltage characteristic of a diode with an appreciable voltage gradient along either the plate or the filament is square law over an appreciable range. Commercial tubes have been tested which can be adjusted to give a square-law characteristic over two decades of voltage or four decades of current. A special diode has been designed and is now under construction in the tube shop. The final multiplier will use four of these diodes.

Multiplying circuits using both types of squarers and adders are now being built. The one using the push-push squarer is now undergoing tests.

## C ELECTRONIC POTENTIAL MAPPING

Staff Dr S Goldman  
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Description of Project In this project an attempt is being made to use radar PPI technique in order to examine and display surface distributions of potential. The novel and difficult features of the problem lie mainly in the development of a practical pickup tube. Among the uses of this technique when developed will be, for example, the examination of the electrical potential distribution on the surface of the skull. It is expected that this will aid in the diagnosis and location of brain tumors, and in the study of normal brain physiology.

Status Work has been done on the preliminary pickup tube mentioned in the last Quarterly Progress Report. With very thorough magnetic shielding and extreme precautions to eliminate extraneous electrical pickup on the accelerating electrodes, the tube was operated down to a level of  $50 \mu\text{v}$ . At this level, the sensitivity was limited by microphonics of the tube elements, and random noise did not yet appear to be appreciable. It thus appears that, with proper supports to reduce microphonics, this type of pickup could be operated at an encephalograph level of  $10 \mu\text{v}$ . It is now felt that the preliminary pickup tube has served its purpose in the study of noise and attention is now being turned to scanning problems. Accordingly, a preliminary pickup and scanning tube having sixteen pickup elements is being constructed to study properties of the scanning process.

## D TRANSIENT PHENOMENA IN WAVEGUIDES

Staff M V Cerrillo

The study of the transient phenomena in lossless waveguides for different terminal conditions has now been completed, and a general and detailed report on the subject is under preparation.

The solutions for the electric and magnetic fields come out in the form of series which converge for all values of  $z$  and for values of  $t \geq z/c$ , where  $t$  is the time,  $z$  the direction of propagation, and  $c$  the velocity of light in the medium. Although these series are formal solutions of the field inside the waveguide they are not very suitable for numerical computation. To avoid this difficulty, approximate summations were obtained for different ranges of the variables, and these have a simple compact form. Also obtained in compact form are very good approximations of the waves' envelopes. The solution of the transient problem also included the distortion of different types of excitation pulses propagated inside the guide, and expressions for the signal velocity and the formation time of the wave. The above calculations were greatly facilitated by the finding of a group of inverse Laplace transforms, a few of which were used in these solutions.

# E BROADBANDING OF A RESONANT IMPEDANCE

Staff R M Fano

In a number of practical cases it is desired to broadband impedances which are representable by means of the simple resonant circuits shown in Figure 1, as for instance, the impedance of a center driven half-wave antenna

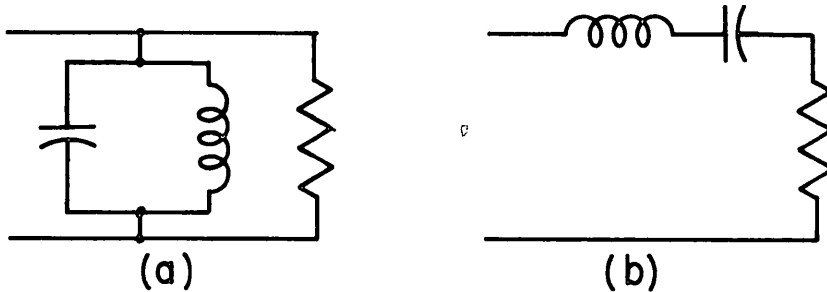


Figure 1 Simple resonant circuits

Let  $\omega_0$  be the resonance frequency of the tuned circuit and  $Q_L$  its loaded  $Q$ . Bode<sup>1</sup> has shown that if  $\rho_{\max}$  is the maximum tolerable magnitude of the voltage reflection coefficient, the maximum theoretical fractional bandwidth in which the reflection coefficient  $\rho < \rho_{\max}$  is given by

$$\left(\frac{\omega}{\omega_0}\right)_{\max} = \left| \frac{\pi}{Q_L \ln \rho_{\max}} \right|$$

The problem of the actual design of a matching network has been attacked by considering the resonant circuit as the last branch of a bandpass ladder filter as shown in Figure 2. The filter is designed to have an input reflection coefficient

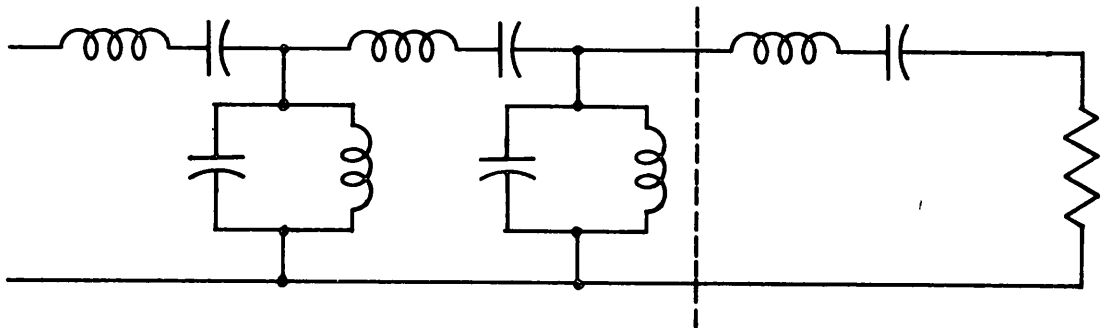


Figure 2 Resonant impedance represented as last branch of a bandpass ladder filter

1 H. W. Bode, "Network Analysis and Feedback Amplifiers", Van Nostrand, New York, N Y, 1945

with a pass-band frequency behavior of the type given in Fig 3.

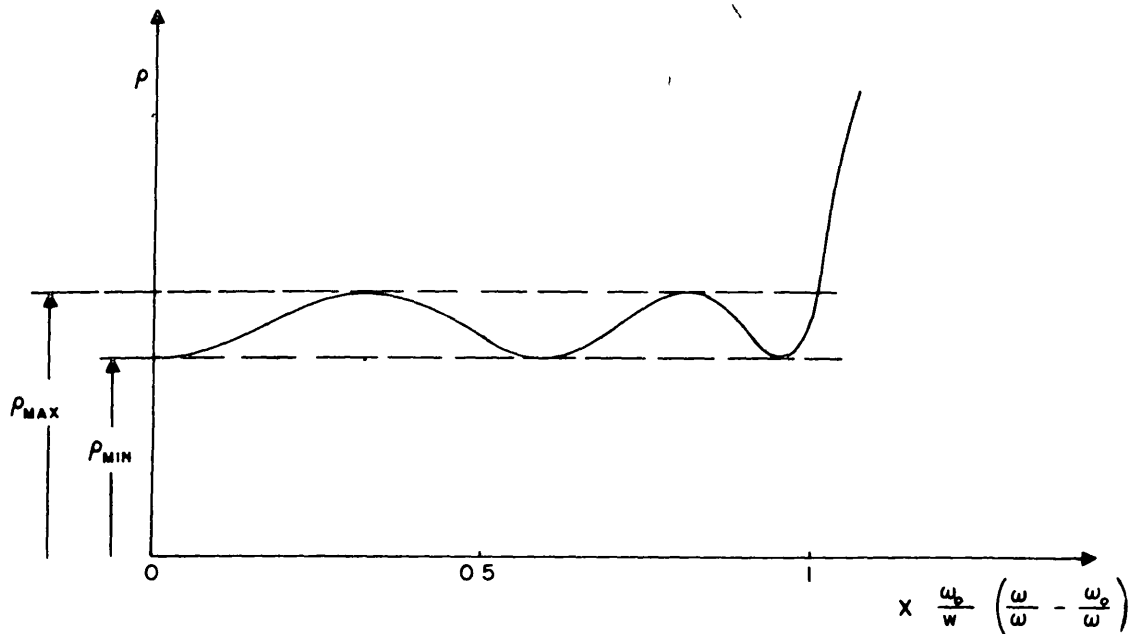


Figure 3 Example of behavior of the reflection coefficient in the pass band.

The optimum ratio  $\rho_{\max} / \rho_{\min}$  is a function of the number of resonant branches in the matching network

The fractional bandwidth approaches the maximum value found by Bode when the number of elements approaches infinity. In practical cases, however, three additional resonant branches in the matching network yield a bandwidth equal to about 80 per cent of the maximum value. The variation of the bandwidth with the total number  $n$  of resonant branches in the ladder structure is shown in Fig 4 for two different values of the maximum reflection coefficient

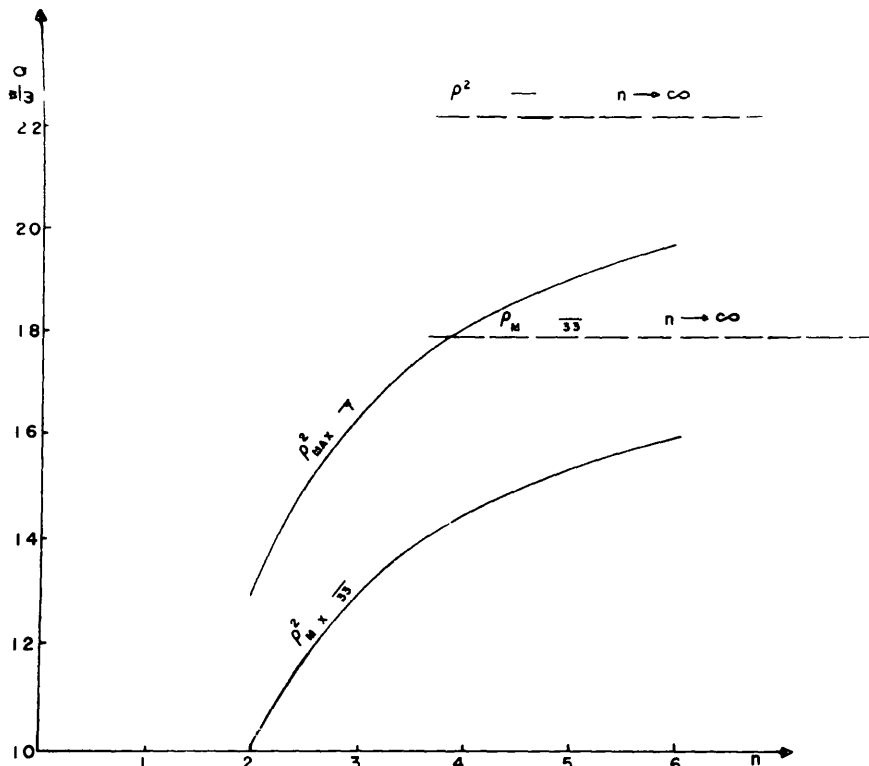


Figure 4 Variation of bandwidth with the number of resonant branches

## F REFLECTION AND TRANSMISSION COEFFICIENTS

Staff R M Redheffer

The theory of reflection and transmission coefficients has been investigated from a new point of view, in which a reflecting object is characterized by its terminals only. A method of "multiplication" of reflections has been devised, and under this system it is found that those classes of objects of special interest in physics have a number of simple group properties. Multiplication may be defined in several ways if we use certain functions of the reflection and transmission coefficients as new variables, one of these definitions has been shown to be isomorphic to matrix multiplication.

A detailed investigation has been carried out on the properties characterizing a lossless object. It is proved, among other things, that such an object always satisfies the reciprocity theorem, except for sign.

The conventional vector diagram for addition of reflections has been investigated with regard to its accuracy and its limitations. These and the above results on reflection are being incorporated in a technical report<sup>1</sup>, the first part of which is being prepared for publication. Another report<sup>2</sup>, which has been written and is also now being prepared for publication, is on the properties of dielectric media with variable parameters. An explicit expression is obtained for the reflection of a dielectric medium of arbitrary thickness, in which the permeability and dielectric constants are proportional and are linear functions of position.

## G COMPUTING MACHINE FOR FOURIER TRANSFORMS

Staff R M Redheffer

The computing machine for Fourier transforms and related expressions is being constructed at the Naval Research Laboratory. It is nearly ready for assembly and should be in operation within a few months. An RLE technical report (No 13) on this device is now in the process of publication.

1 RLE Technical Report No 24

2 RLE Technical Report No 29