Miniaturization of Microwave Assemblies*

LEONARD LEWIN†

Summary—A method of construction is described in which waveguides are arranged in a single plane with adjacent walls common. An assembly is made from a top and bottom plate between which partition walls are arranged to constitute the transmission region. A hybrid-*T* is made from a 3 db coupler, and a microwave repeater is described consisting of five band-pass filters, two hybrid-*T*'s, an isolator, and several other component aspects.

Setting up in situ is achieved by the use of a Bethe hole coupler to monitor the reflection or transmission at a number of specially located check ports.

No electric coupling can be measured across a soldered fabricated waveguide wall.

THERE ARE two basic ways of reducing the bulk and weight of microwave assemblies. The first consists in the reduction in the transverse dimensions of the transmission system employed. This method includes the use of stripline, loaded guide, and ridge guide, and in many cases leads to a loss in performance and tighter tolerances as compared to standard rectangular guide construction. The second method consists in the use of waveguide of standard cross section rearranged topologically so as to form a compact geometrical configuration of components.

Examination of some existing waveguide systems shows that most of the bulk is taken up by flanges, connecting lengths, corners, twists, etc., and by the space which has to be provided to assemble or get at the various pieces. Much of this is occasioned by the three-dimensional layout, the main cause of which would appear to be the familiar hybrid-*T* with its *E*, *H*, and side arms all at right angles to each other. With space at a premium a three-dimensional construction is a luxury. Accordingly a first step towards a compacted arrangement consists in the planarization of the system. This calls for a planar type hybrid-*T*, and a convenient type to use is a simple 3 db directional coupler. The multipost coupler described by Tomiyasu and Cohn[1] is convenient for this purpose and a unit 5.7 inches long with five posts has been constructed for the 4000 mc band. The directivity is in the 20 db range and the power in the straight through arm varies from 44 per cent to 56 per cent in the 7.2 to 8.1 cm band. These figures could no doubt be improved considerably, but for a microwave crystal mixer they are probably adequate.

A second step involves the elimination of connecting pieces and flanges. This brings the walls of adjacent waveguides into contact and makes way for the third step, in which an integral construction is achieved by milling slots in a baseplate and cover-plate and inserting partitions into the slots, thereby creating several waveguide channels side by side. The component aspect is built into these channels before the top plate is fixed on. It has been found that by screwing the partitions to the plates at intervals of one inch the coupling between guides, even in the absence of soldering, is very low. The side walls were a light push fit into the milled grooves, and with the screws loosened the coupling rose to -50 db. Thus despite the fact that the constructional gaps (such as they are) cut the lines of current flow it is possible, for some applications at least, to avoid the necessity of soldering the partitions. It is not easy to say just how small the leakage is when the screws are tight. The limit of detection in these measurements was about -75 db, and at about the -70 db level there was some slight coupling due to leakage at the input flanges; this was in excess of any leakage there may have been through the partition walls themselves. No difficulty was experienced in soft-soldering. An alternative, which was not tried, is to plate the partition wall edges with a thin coating of indium, and to rely on mechanical pressure to achieve an adequate cold weld.

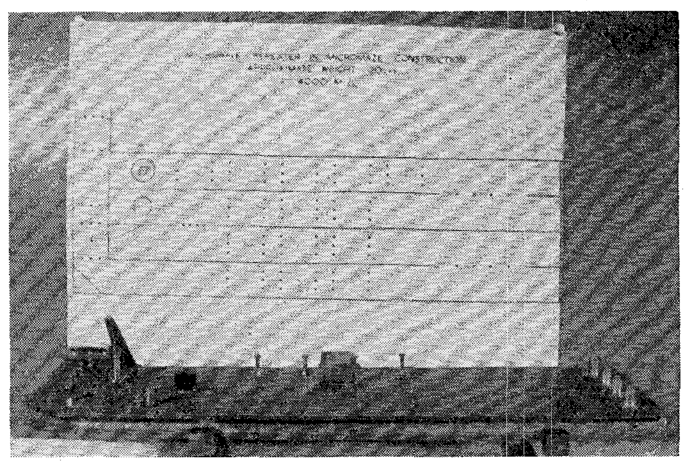

Fig. 1.

Fig. 1 shows schematically the waveguide part of a microwave repeater, together with a block diagram of the functioning parts, made according to the principles outlined above. It has been possible to save an entire repeater bay by this means and to reduce the weight of waveguide by a factor of four. Much of this latter came from the elimination of flanges. The repeater comprises five band-pass filters, two hybrid-*T*'s, a directional

* Manuscript received by the PGMTT, July 16, 1956. Presented before the National Symposium on Microwave Techniques, Philadelphia, Pa., February 2–3, 1956.

† Standard Telecommunication Labs., Progress Way, Enfield, Middlesex, England.

[1] K. Tomiyasu and S. B. Cohn, "The Transvar directional coupler," Proc. IRE, vol. 41, pp. 922–926; July, 1953.

coupler, a load, one unbalanced crystal mixer, two balanced mixers, an isolator, a corner, a local oscillator, and an output for a traveling wave tube. The over-all dimensions are about 1 foot×2 feet 6 inches×1 inch. The isolator, of the resonance absorption type, buffers the local oscillator, which also serves as an output tube, from unwanted frequency components produced in the mixer. Its performance is about 1 db/20 db and its permanent magnet can be seen in Fig. 2. A saving in

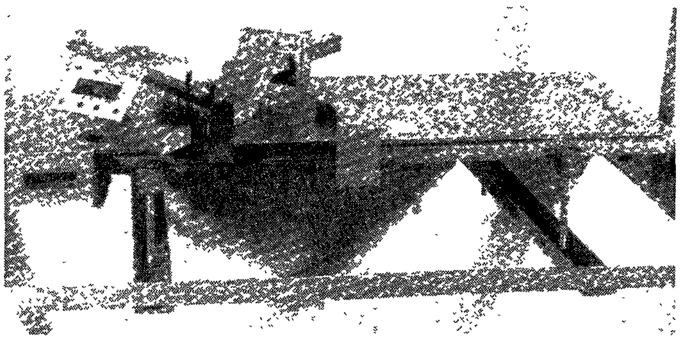

Fig. 2.

length of the band-pass filters was achieved by using triplets of posts across the guide instead of single posts, thus permitting quarter-wave separation of the tuned cavities without higher order mode coupling between them. It is not known how typical this example may be, but a comparison of the new, compact assembly with the arrangement which it replaced was certainly very striking.

The price to be paid for an integrated construction is lack of versatility and inability to alter the design and change components on the one hand, and the need to align components and test them in situ, on the other. The first point makes the method unsuitable for laboratory work, or design of early models. Only at a late stage in the design of equipment is it suitable to go over to the compacted form, or Micromaze, as we have called it.

With regard to testing and matching components in situ, the absence of long and movable connecting pieces between elements makes possible a certain amount of mutual compensation which can be sufficiently broadband for many purposes. In order to align filters, match crystals, etc., it is necessary to insert a signal at certain positions and also to monitor the response at other positions. In the case of the repeater of Fig. 1, there are a number of "natural" entry points, such as the local oscillator input, the crystal mount positions, and so on. A complete test procedure has to be prescribed, with each component tuned or lined up in order, and it was found that to do this efficiently eight additional monitor positions were needed. Each of these took the form of a hole, $\frac{5}{8}$ inch diameter, which was plugged under normal conditions. (No discontinuity at a plugged hole could be detected.) In order to insert or extract a signal the plug is removed, and a monitor guide is coupled by means of a short boss with a $\frac{5}{8}$ inch diameter bore. The coupling is of the type known as a Bethe hole coupling, and with the monitor guide at about 35° to the main axis—the angle is not critical to within a degree or two—a directivity of 30 db is readily obtained. In order to improve this to a figure in excess of 40 db over a 20 mc band a slight screw insertion in the coupled arm is used to cancel out the small remaining wave. In use, the monitor arm is clamped to the sides of the repeater, as shown in Fig. 2. and once the angle is set it can be maintained for any movement of the guide over the test piece. In fact the monitor is set up, once and for all, by using a subsidiary guide mounted parallel to the repeater axis and the correct angle and trimmer screw insertion found. Although it is not certain to what extent the accuracy of setting is maintaned, test filters in isolated guide tuned by this "in situ" method had responses in no way inferior to those tuned by more conventional methods. For these measurements a swept frequency bench and cro display were used. By the use of a movable and calibrated probe in the coupled arm it is possible to produce a reflection which exactly cancels the reflection produced by the test piece, and in this way measurements of both the amplitude and phase of the reflections can be made. For example, the input to the repeater, consisting of a tuned filter and an unbalanced mixer could be tuned readily under active conditions to a (voltage) reflection of the order of 1 per cent over a 14 mc band, this being the limit provided by the filter.

A fuller description of the test apparatus will appear in a later paper. It may be added here, however, that one of the difficulties encountered was the need to deal with very small signals, since the Micromaze is tested under low signal conditions. Thus, if 10 microwatts of input signal incident on the input mixer crystal is reflected with a one per cent voltage reflection coefficient then it becomes necessary to measure signals at the −60 dbm level. The coupling coefficient of the coupler is −35 db so that when there is no direct entry a further attenuation of the signal occurs: fortunately in these positions a somewhat larger incident signal can be used. In order to deal with these small signals a superheterodyne receiver is used, and since the frequency is being swept over something like 120 mc the local oscillator must keep closely in step if the necessary signal to noise is to be achieved. It was eventually decided to derive the local oscillator signal directly from the swept frequency oscillator by beating in a high level crystal mixer. An intermediate frequency of 1000 mc was chosen so that the various beat frequencies and other harmonics could be adequately dealt with. The 1000 mc signal after detection was mixed with a subsidiary signal at 940 mc and the resulting signal amplified in a conventional 60 mc receiver.

The author wishes to acknowledge the assistance of his colleagues in carrying out the work described above, in particular, H. Grayson who originally conceived the idea of compacting the waveguide, and G. Craven who did much of the associated design and measurements.