A Compact 8-In, 8-Out Multiport Amplifier with Novel Three-Dimensional Structure

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***Abstract*—A novel three-dimensional (3-D) structure is proposed for an 8-in, 8-out multiport amplifier (MPA). The amplifier consists of two 16-port directional couplers and eight amplifier units. This structure can realize more compact amplifiers that do not require any cable adjustment. To confirm the proposed structure, a MPA is constructed and tested at 2.0 GHz.**

***Index Terms*—Multiport amplifier, 16-port directional coupler, 3-D structure.**

I. Introduction

A multiport amplifier (MPA), which consists of two $N \times N$ matrix networks and N amplifier units, offers the advantage of equalizing power level among the N amplifier units [1], [2]. Input signals are equally divided and fed to N amplifier units. After amplification, each signal is collected. In other words, amplifiers are shared among the signals. This property is very effective for multichannel satellite transponders [1] and multibeam satellite transmitters [2]. Also, in adaptive antenna arrays for mobile communication systems [3] where the powers transmitted from the antenna elements are not equal and vary with time, it is a very effective way of reducing the saturation power of each amplifier unit.

One drawback of the MPA is its complicated circuit structure. In [2], the amplifier is composed of 24 quadrature hybrids and eight amplifier units, and they are connected by coaxial cables. Moreover cable length must be very carefully adjusted. Any difference in cable length degrades the amplifier performance. More compact and simple structures are required when installing the amplifier in the base stations of mobile communication systems.

The purpose of this study is to develop a compact MPA. In this paper, we present a novel three-dimensional (3-D) structure for an 8-in, 8-out MPA (8-MPA). Proper operation is confirmed through experiments.

II. Design and Construction

In this paper we focus on the construction of an 8-in, 8-out device consisting of two 16-port directional couplers and eight amplifier units. A MPA is best understood as an extension of a balanced amplifier. The fundamental circuit configuration of the MPA is shown in Fig. 1(a). Eight amplifier units are preceded by a multiport directional coupler and are followed by an identical coupler.

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Eight input signals are divided into eight in the multiport directional coupler. At each amplifier unit, the signal power from one input port becomes one-eighth and it is combined with the other seven signals from the other input ports. The phase of each signal must have the correct relationship. The eight sets of combined signals are amplified by the amplifier units. The amplified signals are collected by the multiport directional coupler at the output and the eight amplified original signals are regenerated. It is noted that the power into the amplifier units is uniform even if there is a large difference among the power levels of original input signals. In this way the MPA offers improved performance in terms of consumption power and fabrication cost.

The existing 16-port directional coupler consists of 12 quadrature hybrids [4] and they are connected by 16 cables. Since cross wiring is needed, it has been impossible to manufacture a fully integrated 8-MPA using planner transmission lines in same way as 8-port couplers [5], [6]. However, it becomes possible if a 3-D layout is used.

Fig. 2 shows (a) the proposed structure of a 16-port directional coupler and (b) an 8-MPA. Fig. 2(a) shows the construction of a directional coupler without any crossing cables such as #2, 3, 6, 7, and 8 in Fig. 1. In Fig. 2(b), the two 16-port directional couplers are placed on two sides, the inner and outer sides, of a metal base. The directional coupler consists of twelve branch-line quadrature hybrids which are made of four microstrip lines. They are directly connected to each other. Eight amplifiers are connected to these couplers by microstrip lines and through-holes.

An advanced form of this 8-MPA uses a multilayer substrate, as shown in Fig. 3(a). Fig. 3(b) shows the structure of two couplers in detail. One 16-port directional coupler is manufactured on the inner layers using striplines and the other is manufactured on the outer layers using microstrip lines. The layers are connected using through-holes. The eight amplifier units are put on the top and bottom layers in Fig. 3(a). The feature of this structure is that the 16-port amplifier can be formed on a single multilayer substrate without any crossing cables.

Another advantage of this amplifier is that there is no need to adjust cable length to maximize amplifier performance. The new structure eliminates this problem due to its symmetrical configuration. In addition, it is suitable for volume production.

III. Experimental Results

An experimental 8-MPA with the structure in Fig. 2(b) was constructed and tested. A photograph is shown in Fig. 4. The design center frequency was 2.0 GHz. A 0.035 mm thick copper-clad substrate with a dielectric constant of 2.6 was used. Commercially available MMIC amplifier chips were used as

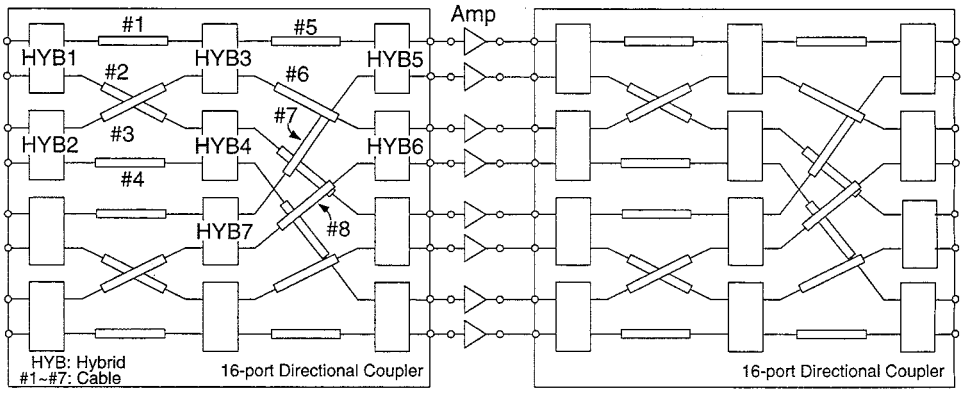

Fig. 1. Fundamental circuit structure of 8-in, 8-out multiport amplifier using the existing configuration of 16-port directional couplers.

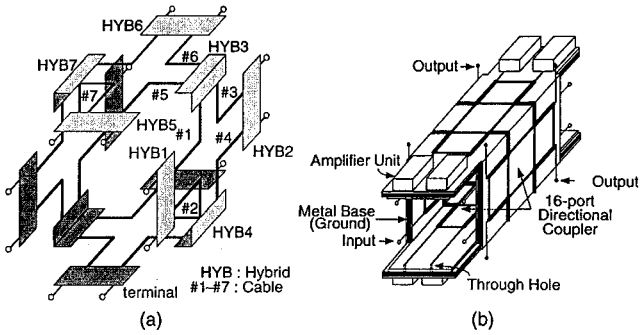

Fig. 2. Proposed structure: (a) 16-port directional coupler without any crossing cables and (b) 8-in, 8-out multiport amplifier.

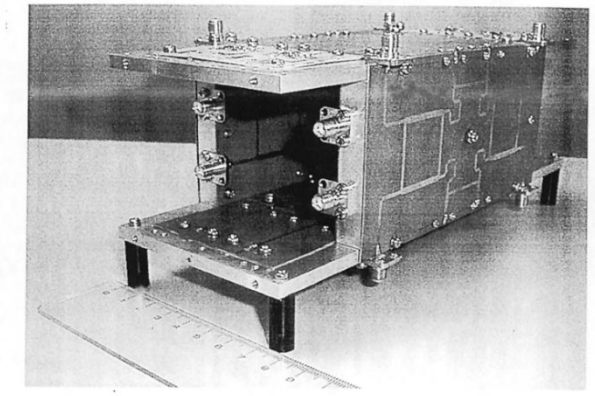

Fig. 4. Photograph of the constructed amplifier.

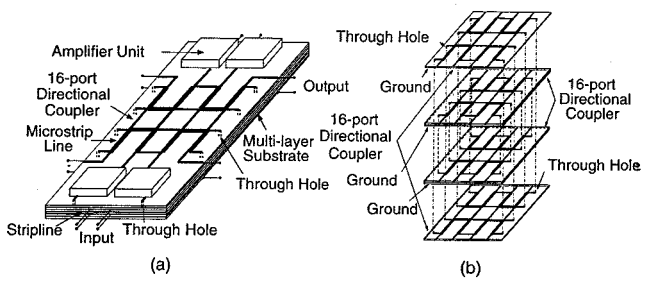

Fig. 3. Multiport amplifier using multilayer substrate:(a) integrated 16-port amplifier using multilayer directional couplers and (b) structure of 16-port directional coupler integrated into a multilayer substrate.

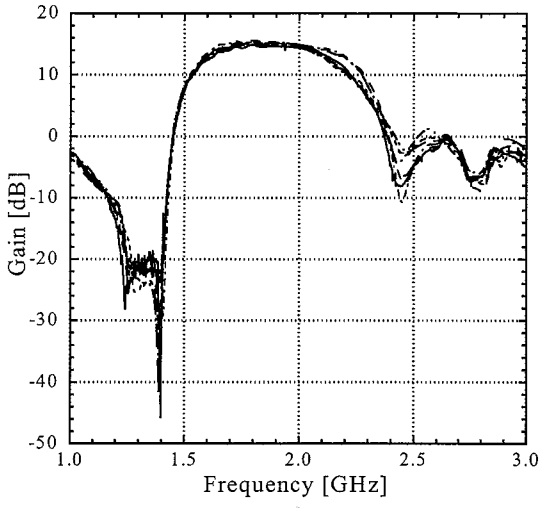

Fig. 5. Gain performance of the constructed 16-port amplifier. Eight curves are plotted.

amplifier units. Gain and phase deviation of them is negligibly small. $\lambda/4$ transmission lines were inserted between hybrids for the purpose of broadening the bandwidth [6], [7]. The coaxial connectors shown in Fig. 4 are for the input and output ports and the eight amplifiers are seen on the outer side.

The insertion loss of the two 8-port directional couplers, measured using through transmission lines instead of amplifiers, was about 2.3 dB at 2.0 GHz. The measured gain performance of the amplifier for eight input ports is shown in Fig. 5. The gain difference among them was less than 0.3 dB. Thus, the result shows that the 8-MPA is well balanced without any cable adjustment.

Output power performance is shown in Fig. 6. P-1 dB output power of the constructed 8-MPA was about 30 dB. The performance of one amplifier is also shown. Considering the insertion loss of the two 16-port directional couplers, this performance is acceptable.

IV. Conclusion

A novel 3-D structure for an 8-in, 8-out multiport amplifier was proposed and demonstrated experimentally. It can be man-

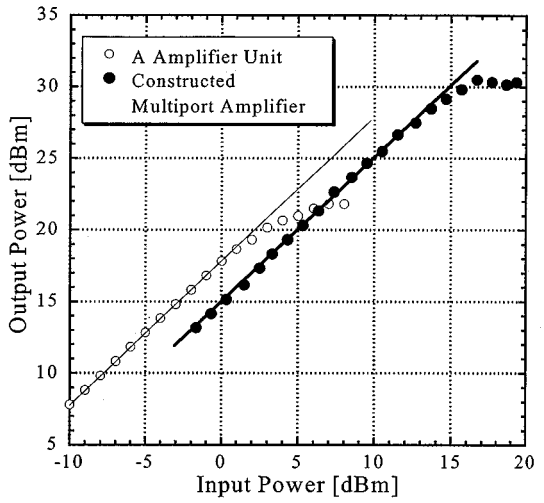

Fig. 6. Output power performance of 16-port amplifier. That of one amplifier unit is also plotted.

ufactured in a fully integrated form using planner transmission lines. The amplifier offers the advantages of easier fabrication, less adjustment, and small size. It is very suitable for low-cost applications such as antenna array systems for mobile communication.

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