50W CLASS MULTI-PORT AMPLIFIER FOR MULTI-BEAM SATELLITE COMMUNICATIONS

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ABSTRACT

A Multi-port Amplifier (MPA), composed of an array of high power amplifiers (HPAs), a power divider and a power combiner, is suitable for on-board transponder in a multi-beam mobile satellite communications system. A 50W class experimental MPA composed of 8 HPAs has been developed based on a design method which takes account of the nonuniformity of HPA characteristics. It has exhibited excellent performance.

1. INTRODUCTION

In a multi-beam mobile satellite communications system, traffic distribution among the multiple beams fluctuates over time. This makes the on-board transponder to operate at low transmission power efficiency in a conventional system where an on-board high power amplifier (HPA) is allocated to each beam. A unique amplifier system, called the MPA (Multi-port Amplifier), is a promising candidate for solving this problem [1]. The MPA is composed of an array of HPAs, a power divider and a power combiner. Multiple input signals, each corresponding to a respective beam, are distributed to all HPAs by the power divider, jointly amplified at the amplifier stage, and then combined by the power combiner and transmitted to the output port corresponding to a particular input port. The input signal from one port is thereby sent to a specified output port.

Although the MPA has a lot of features [1, 2], its configuration is complex and the deviation in characteristics, common in HPAs, negatively affects ideal MPA performance. Nonuniformity of HPA characteristics causes the loss of combined power and gives rise to leakage power outputs to other ports, which results as interference signals to degrade isolation among the multiple ports. Low combined power loss and high isolation are required for an MPA, under the condition that its HPAs are nonuniform.

The relations of the MPA's combined power loss and isolation characteristics to HPA gain and phase deviations have been clarified by an analytical design method that takes account of the nonuniformity of HPA characteristics. A 50W class experimental MPA composed of 8 HPAs has been developed based on this design method, and its performance is described in this paper.

2. MPA CONFIGURATION

In general, an MPA is composed of m input and output ports, n ($n \geq m$) HPAs, a power divider and a power combiner. A power divider and combiner are composed of 90° hybrid networks when the number of HPAs n is a power of 2 ($n=2^{\prime}$).

The configuration of a 50W class experimental MPA composed of 8 HPAs is shown in Fig. 1. The 50W output power is delivered by combining the output power of the 8 HPAs with each output power being higher than 38 dBm.. Radio channels can be assigned flexibly by varying the number of channel allocation in each port without power efficiency degradation. In an extreme case, all power or all channels can be concentrated on one port when all signals are input to one port. The transmission capability is determined by the sum of HPA output power, independent of traffic imbalance.

A compact and low loss power combiner composed of 90° hybrid networks has been developed and

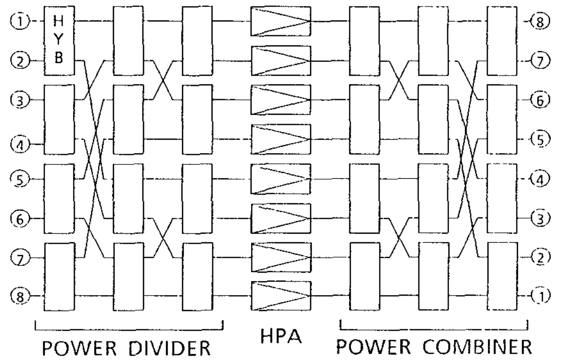

Fig. 1. Configuration of a 50W class experimental MPA composed of 8 HPAs.

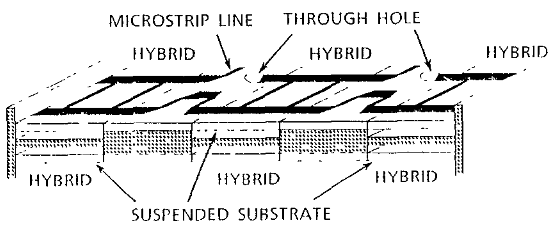

Fig. 2. Cross section of the power combiner.

implemented. All hybrids are fabricated on suspended substrates and connected by microstrip lines. Microstrip line crossovers are implemented using through holes. A cross section of the power combiner is illustrated in Fig. 2.

3. ALLOWABLE HPA CHARACTERISTIC DEVIATION [3]

In practical applications, virtually all HPAs have gain and phase characteristics somewhat deviated from ideal ones. Deviation in HPA characteristics degrades combined power and gives rise to leakage power outputs to other ports, which results as interference signals. Combined power loss is defined as the ratio of the sum of each HPA's output power P_0 to the MPA output power P_{out} at a specified port. Isolation is defined as the ratio of P_0 to P_{iso}, the maximum among leakage power levels at the isolation ports. An isolation port is defined as a port at which no output is obtained in an ideal case.

When the u-th HPA's characteristics is given by A_u, the combined power loss η is represented by

$$\eta = \frac{P_0}{P_{out}} = \frac{n \sum_{u=1}^{n} |A_u|^2}{|\sum_{u=1}^{n} A_u|^2} \quad (1)$$

When n HPAs' gain and phase values distribute uniformly within $G_0 \pm \Delta G$ and $\theta_0 \pm \Delta\theta$, respectively, the gain and phase values of each HPA are given by

$$G_j = G_0 + \frac{(2j-1-n)\Delta G}{n-1} \quad (2)$$

and

$$\theta_i = \theta_0 + \frac{(2i-1-n)\Delta\theta}{n-1} \quad (3)$$

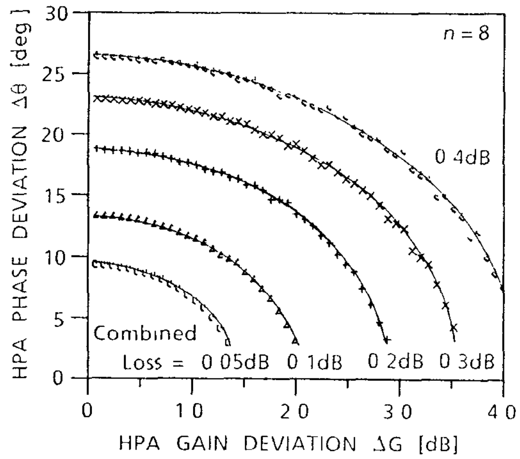

Fig. 3. Computer simulated combined power loss characteristics as a function of HPA gain deviation ΔG and HPA phase deviation Δθ.

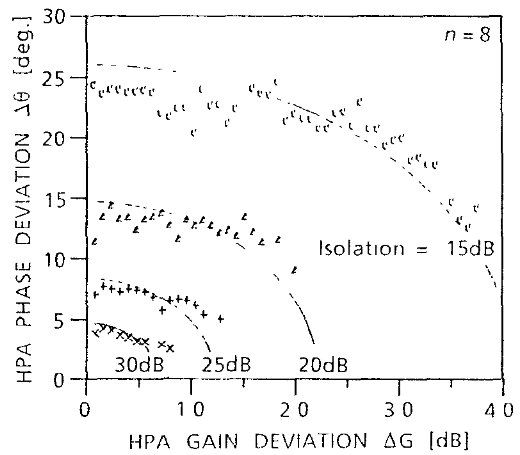

Fig. 4. Computer simulated isolation characteristics as a function of HPA gain deviation ΔG and HPA phase deviation Δθ.

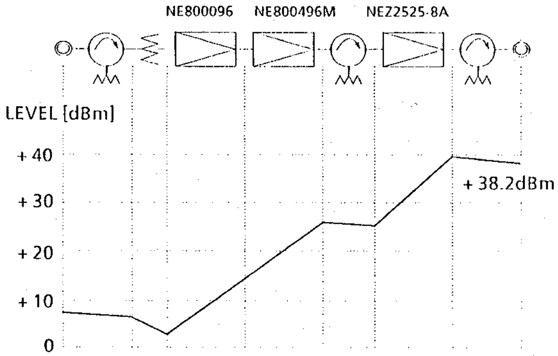

Fig. 5. Block diagram and level diagram of HPA.

The computer simulated combined power loss characteristics are shown in Fig. 3 as a function of HPA gain deviation ΔG and HPA phase deviation $\Delta\theta$ when $n=8$. The computer simulated isolation characteristics are shown in Fig. 4. Here, Au is determined by randomly combining gain and phase values of Eqs. (2) and (3).

According to these results, in order to construct an MPA whose combined power loss is less than 0.1 dB and whose isolation is more than 20 dB when the MPA is composed of 8 HPAs, the gain deviation of each HPA must be controlled to within ± 1 dB, and its phase deviation must be controlled to within ± 10 degrees.

A 50W class experimental MPA was constructed with 8 HPAs. A block diagram and level diagram of an HPA is shown in Fig. 5. The 8 HPAs' gain and phase deviation ΔG and $\Delta\theta$ are shown in Fig. 6, where the deviation was calculated as half of the difference between the maximum and minimum values at the same input level. It was possible to construct 8 HPAs whose gain deviation was within ± 0.3 dB and phase deviation within ± 8 degrees up to the 1 dB gain compression point. These results predict better MPA performance than the above example.

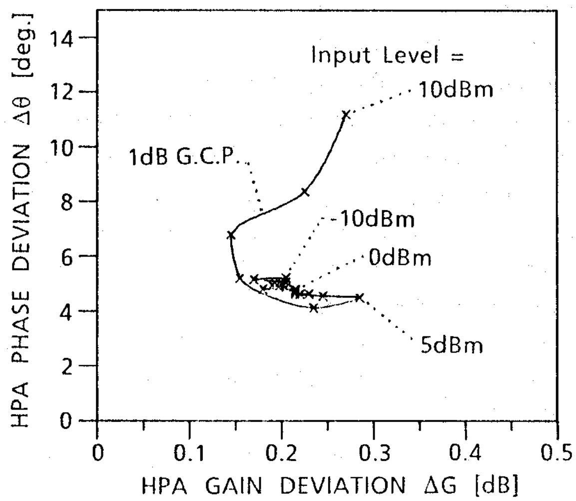

Fig. 6. 8 HPAs' gain and phase deviations, where the deviation was calculated as half of the difference between the maximum and minimum values.

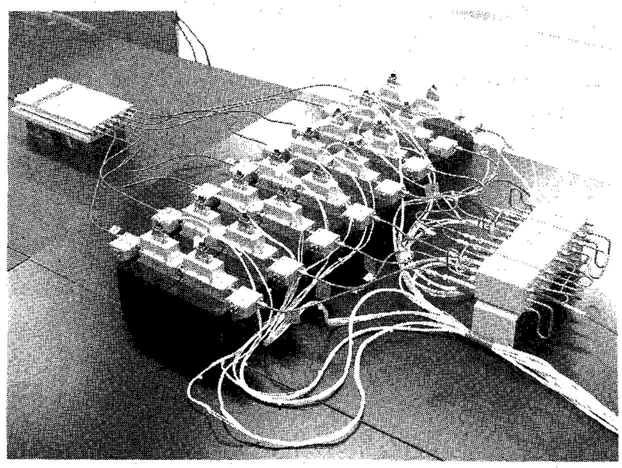
Fig. 7. Photograph of the developed MPA.

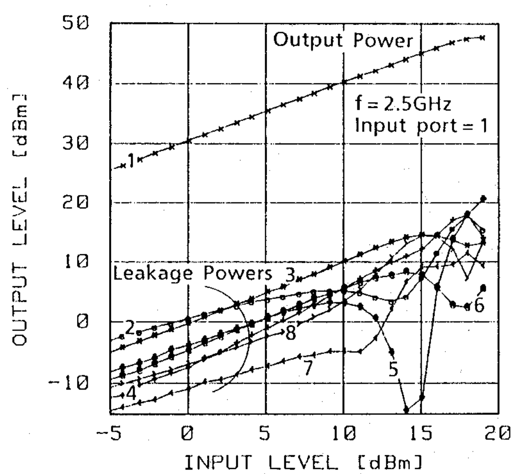

Fig. 8. Input-output characteristics of the developed MPA.

4. MPA PERFORMANCE

A 2.5 GHz band 50W class experimental MPA was developed to confirm the analytical results and high power delivery. Figure 7 shows a photograph of the developed MPA.

The input-output characteristics of the MPA are shown in Fig. 8. Output and leakage powers were measured when a 2.5 GHz signal was input to port 1. More than +47 dBm MPA output power with 35% DC to RF efficiency was obtained at the 1 dB gain compression point. The combined power loss of the developed MPA due to HPA nonuniformity, including the power combiner's loss, was about 0.5 dB and the isolation was about 30 dB at a 20 dB dynamic range up to the 1 dB gain compression point. Since the power combiner's loss was about 0.5 dB, the combined power loss of the MPA due to nonuniformity of HPA characteristics was negligible.

The MPA's frequency response in the 100 MHz band is shown in Fig. 9. Gain flatness was less than 1 dBp-p in the 100 MHz band. A broadband MPA can be achieved because it has no filtering elements.

A summary of the developed MPA's performance is shown in Table 1. A 50W class experimental MPA composed 8 HPAs has been confirmed to have excellent performance.

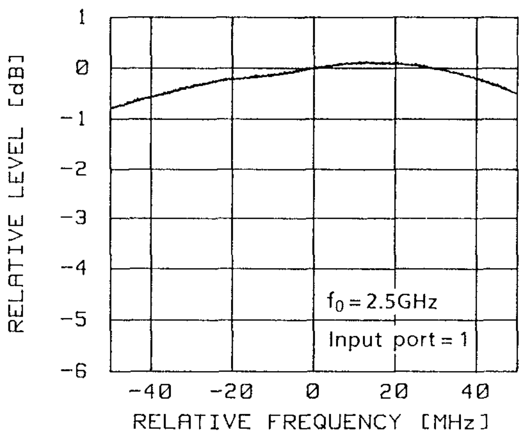

Fig. 9. Frequency response of the developed MPA.

Table 1. 50W class MPA performance summary.

PARAMETER	PERFORMANCE
Number of Input/Output Ports	8
Frequency Band	2.5GHz Band
Output Power (at 1 dB G C P)	56 W
Power Consumption (at 1 dB G C P)	160 W
Linear Gain	More than 30 dB
Gain Flatness (in 100 MHz Band)	Less than 1 dBp-p
3rd Intermodulation Distortion (at 1 dB G C P)	C/IM3 > 17 dB

5. CONCLUSION

The MPA is a promising system as an on-board high power amplifier in multi-beam mobile satellite communications. Allowable gain and phase deviations for the multiple HPAs were clarified by an analytical design method that takes account of the nonuniformity of HPA characteristics. A 2.5 GHz band 50W class experimental MPA composed of 8 HPAs, whose gain deviation was within ± 0.3 dB and phase deviation within ± 8 degrees, was developed. A compact and low loss power combiner composed of 90° hybrid networks was also developed and implemented. The developed MPA exhibited excellent performance.

A 100W class MPA is now under development. This MPA system is planned to be on board the Japanese ETS-VI satellite, which will be launched in 1992, to investigate its applications in mobile satellite communications [4, 5].

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