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# A Novel CPW Balanced Distributed Amplifier Using Broadband Impedance-Transforming MEMS Baluns

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**Abstract** – A novel balanced distributed amplifier (DA) was proposed using novel impedance transforming MEMS baluns. The impedance transforming MEMS balun is matched to 50Ω at one input port and 25Ω at two output ports. It is based on the electric field mode-change method, thus it is strongly independent of frequency and very compact. The novel balanced DA consists of two 25Ω-matched DAs and these are combined by 50Ω-to-25Ω baluns. Theoretically, it has two times wider bandwidth and power capability than the conventional DA. So as to verify the proposed concept, we designed and fabricated a conventional DA and the proposed one using 0.15-$\mu$m GaAs pHEMT technology.

**Keywords**: MEMS, Balun, Balanced, Distributed amplifier, CPW

## 1. Introduction

The principle of distributed amplifier (DA) was proposed by Percival in 1936 [1]. This new concept made it possible to obtain amplification over much wider bandwidth than conventional amplifier circuit techniques. For a larger power capability, a balanced structure combining two unit DAs with a power divider/combiner is suggested [2]. The authors designed wideband 180° hybrid coupler whose bandwidth is from 5 to 11GHz and fabricated a 5-11GHz balanced distributed power amplifier. However, the combining structures cannot have the bandwidth as wide as the DA. Recently, a mode-change impedance transforming balun using a MEMS overlay structure is proposed [3]. This balun is matched to 50Ω at one input port and 25Ω at two output ports and has extremely wide bandwidth. In this report, we proposed a novel balanced DA topology combining two 25Ω-matched DAs with this impedance transforming ultra broadband MEMS baluns of [3]. This novel balanced DA structure shows the possibility of overcoming the limitations of a conventional 50Ω-matched DA.

## 2. Study of the New Topology

Basic design guidelines for a conventional DA have been reported [4, 5]. The basic DA structure is shown in Fig. 1, wherein the gain-producing FET devices are distributed and separated by delay line elements. FETs' gate-to-source capacitances ($C_{gs}$) are combined with transmission lines to form lumped-element LC artificial transmission lines. The delay line connecting the gates is referred to as the *gate line* and that connecting the drains is the *drain line*. Assuming ideal components, unilateral active devices, termination impedances that are matched to the artificial line impedances, and gate- and drain-line phase synchronization, the general expression for the amplification is

$$G = \frac{n^2 g_m{}^2 Z_0{}^2}{4} \tag{1}$$

where n is the number of FETs, $Z_0$ is the characteristic impedance of the artificial transmission lines and $g_m$ is the transconductance of FET. The inductor and capacitor values are critical in determining the line cutoff frequency and the characteristic impedance [6].

$$f_c = \frac{1}{\pi \cdot \sqrt{L \cdot C}} \tag{2}$$

$$Z_0 = \sqrt{\frac{L}{C}} \tag{3}$$

The ordinary radio frequency systems are based on 50Ω, so $Z_0$ is fixed to 50Ω. Thus (2) and (3) can be written as the followings.

$$L = Z_0{}^2 \cdot C \tag{4}$$

$$f_c = \frac{1}{\pi \cdot Z_0 \cdot C} \tag{5}$$

From (4) and (5), we can find that capacitance C, or $C_{gs}$, is crucial in determining the line length between FETs and bandwidth of DA. Ideally, $C_{gs}$, $g_m$ and power capability are proportional to the FET's gate width. Thus, (5) shows the

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trade-off relationship between the power capability and the bandwidth of DA. If the gate and drain line characteristic impedance is less than 50Ω, limitations mentioned above can be overcome. Assuming $Z_0$ to be 25Ω, the line length between FETs can be reduced to four times according to (4). Also the bandwidth of DA can be two times wider than that of conventional 50Ω-matched DA, maintaining the FET gate width. Although (1) shows that the gain is degraded by 6dB, gain can also be maintained by cascading more n FETs assuming the ideal lossless case. However, communication system requires 50Ω-matched circuits, thus, 50Ω-to-25Ω impedance transformer should be placed at input and output ports of 25Ω-matched DA. Fig. 2 shows the schematic of the proposed balanced DA using two 25Ω-matched DAs and two 50Ω-to-25Ω impedance transforming baluns.

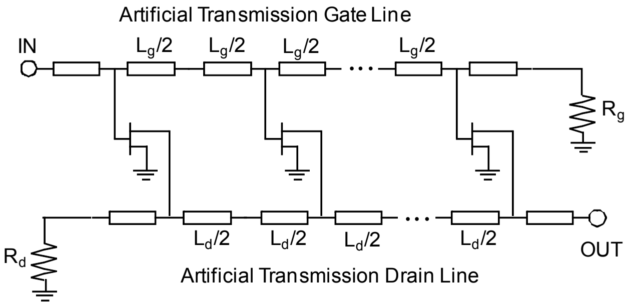


**Fig. 1.** Schematic of conventional distributed amplifier

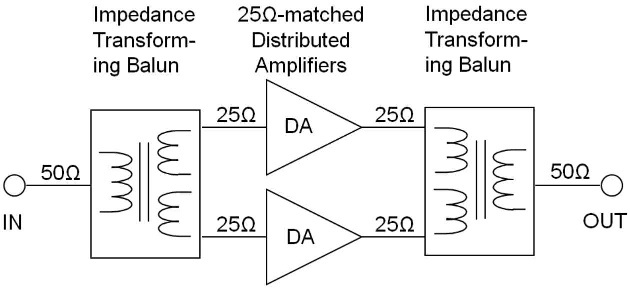


**Fig. 2.** Schematic of novel balanced distributed amplifier

## 3. Fabrication and Measurement

Fig. 3 shows the CPW ultra-broadband impedance transforming MEMS balun structure and the transformation of electromagnetic wave directions, proposed firstly at [3]. The signal line of port 1 passes through to port 2. The ground planes of port 1 are combined over the signal line of port 1 by air-bridge process and then pass through to port 3. The unbalanced input signal changes its mode to balanced at the air-bridge overlay parallel plates and then the two split signals return to unbalanced mode by introducing common ground (CG) planes. The output two signals have same magnitudes while the phase difference between two output ports is 180º. The reason why the proposed balun has extremely wide bandwidth is that it doesn't use transmission line structure which is strongly frequency dependent but changes the incident wave mode at small areas. The size of this balun is 0.4 mm×0.3 mm and that is very small compared with ordinary Marchand-type baluns.

Using this MEMS balun, we verified the proposed balanced DA topology. A conventional 50Ω-matched DA and a novel balanced DA were designed and fabricated using 0.15μm GaAs MMIC process [7]. Fig. 4 shows the photograph of the fabricated DAs. Both DAs have FETs of 50μm gate width. The chip sizes are 1mm × 2.45mm for the conventional DA and 1.15mm × 2.65mm for the

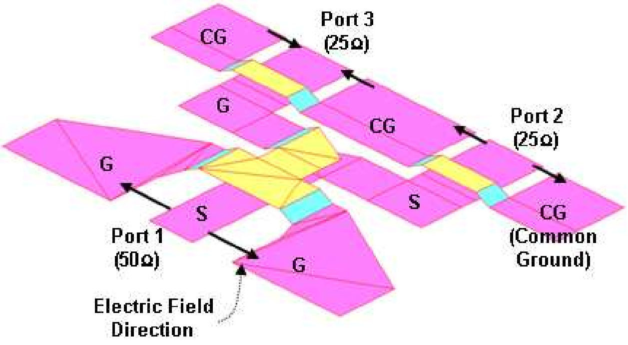


**Fig. 3.** Structure of impedance transforming MEMS balun

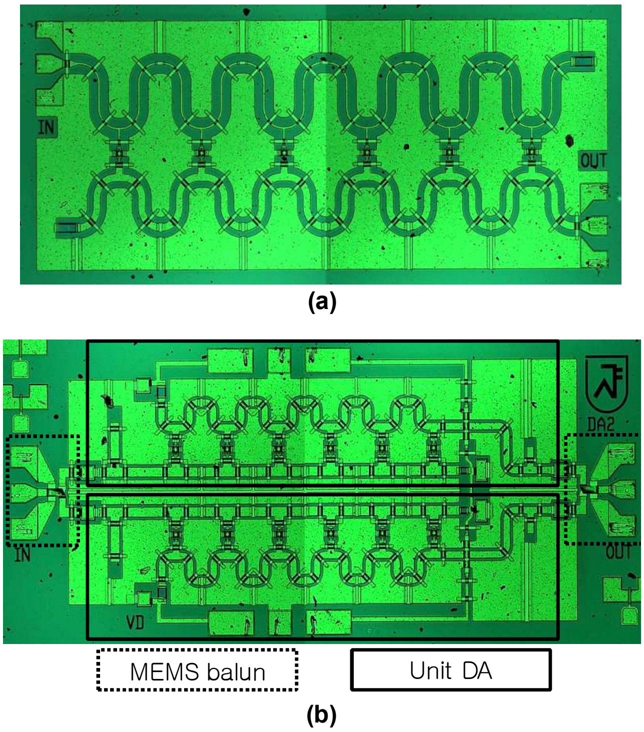
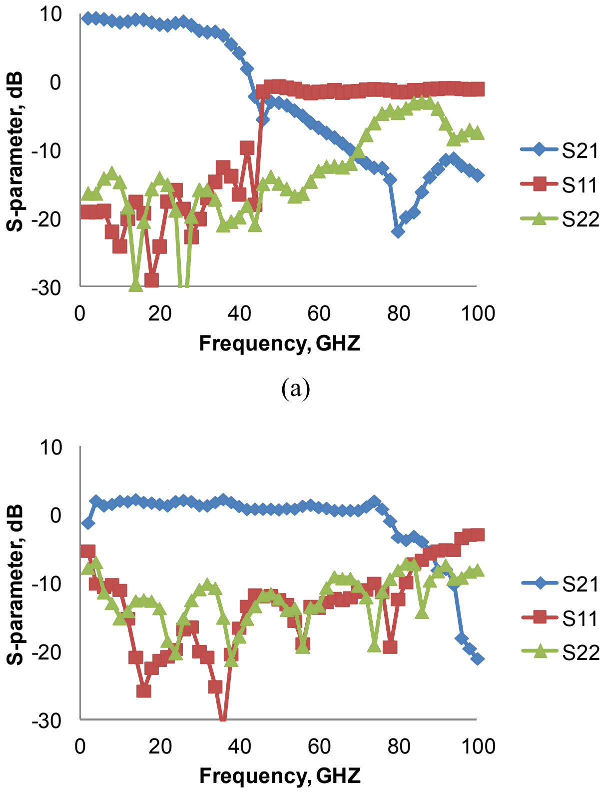


**Fig. 4.** Photograph of the fabricated: (a) conventional 50Ω-matched DA and; (b) novel balanced DA. Chip sizes are 1.0 mm×2.45 mm and 1.15 mm×2.65 mm, respectively.



(a)

(b)

**Fig. 5.** Measured results of (a) conventional 50Ω-matched DA and (b) novel balanced DA.

proposed one. Because the gate or drain line lengths of the novel structure are shorter than the conventional one according to (4), the overall chip size of novel structure is slightly larger than that of conventional DA in spite of two baluns and two six-cell DAs. Fig. 5 shows the measured scattering parameters of both DAs. The conventional DA has 37GHz bandwidth with average gain of 8.4dB and the balanced DA has 2-76GHz bandwidth with average gain of 1.5dB. The bandwidth of novel balanced DA is almost two times wider than that of the conventional DA. Ideally, the novel DA's gain is 6dB less than that of the conventional one from (1), but the loss of the input and output baluns are added.

## 4. Conclusion

A novel CPW balanced DA topology was proposed using ultra-broadband impedance transforming MEMS baluns. The balun is matched to 50Ω at one input port and 25Ω at two output ports. It is based on the electric field mode-change method, thus it is strongly independent of frequency and very compact. Theoretically, the novel DA structures can obtain two times larger power capability and bandwidth compared with conventional 50Ω-matched DA. To verify this concept, we designed and fabricated a novel balanced DA using 0.15μm GaAs pHEMT process and confirmed the possibility of the proposed novel DA structure.

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