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**Abstract**—This work presents an examination of the outphasing amplification system called also LINC (Linear amplification using non linear components) with two kinds of Wilkinson combiners, one is matched and the other one is unmatched. The Wilkinson combiner is called unmatched when the one hundred ohms resistor at its inputs is eliminated. The study is done with a frequency band from 1 GHz to 4 GHz to show the performance response of the two systems in function of the signal phase variation. In section two, the system with matched combiner is studied and we present some graphics done on ADS simulator. These graphics show clearly the combiner input impedances, the drain current the power efficiency and the signal linearity of the system in function of the phase variation for the entire frequency band. In section three the same simulation is done to show the same graphics, but the outphasing system is using this time an unmatched Wilkinson combiner. The comparison of the two system behaviors demonstrates that the linearity is conserved very well in both but for the power efficiency the unmatched combiner behaves better.

**Keywords**—Outphasing LINC; matched Wilkinson combiner; unmatched combiner; class-B amplifier; transmission line; efficiency; linearity.

## I. INTRODUCTION

The outphasing amplifier system [1] is an efficient system that use non linear components in order to produce linear output signal, called also LINC [2][3]. This technique is a method of vector summing of two constant amplitude phase modulated signals and amplified by saturated power amplifiers. Fig. 1 simplifies the signal processing in this kind of amplifiers. The principle of the LINC technique is to convert the amplitude modulation of the input signal  $S(t)$ , into two constant envelope and phase modulated signals  $S1(\theta)$  and  $S2(-\theta)$ .

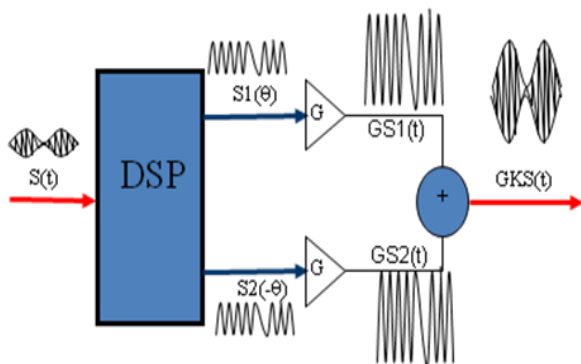


Fig. 1. The outphasing amplification system.

These two signals are then amplified with two saturated amplifiers and finally added by a combiner to produce at the output a linear signal comparing with the input and good power efficiency [4].

This work is concentrated on the use of two kinds of combiners in order to combine the two signals provided from the saturated amplifiers. We will study and test the effect of large frequency band on the performance of LINC for every combiner, one is the matched Wilkinson combiner, and the other is the unmatched Wilkinson combiner.

Fig. 2 shows a matched Wilkinson combiner. It is called unmatched, when the 100Ω resistor is eliminated.

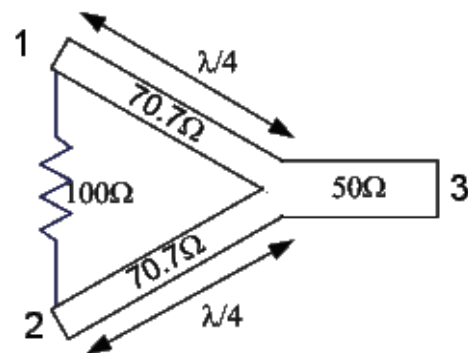


Fig. 2. Matched Wilkinson combiner.

The Wilkinson combiner is fabricated with two quarter wavelength transmission lines with characteristic impedance of  $\sqrt{2}Z_0 = 70.7\Omega$  if  $Z_0 = 50\Omega$ . The 100Ω resistor is to ensure impedance matching of 50Ω in front of the two amplifiers. When we eliminate this resistor, the amplifiers will see unmatched impedances at the combiner inputs, which that may produce reflection coefficient back to the amplifiers.

In the next two sections, the outphasing amplifier is tested using the two combiners in function of large band of frequencies to see their effect to the power efficiency and the signal linearity of the amplification system.

## II. OUTPHASING AMPLIFIER WITH MATCHED COMBINER

In this section we will examine the outphasing amplifier with a matched Wilkinson combiner for three different frequencies. The combiner is fabricated with quarter wavelength transmission lines corresponding to one of these frequencies named  $f_0$ , and the characteristic impedance of the combiner lines is  $\sqrt{2}Z_0=70.7\Omega$ . The second frequency equals  $f_0/2$  and the third equals  $2f_0$ . Fig. 3 represents the

outphasing amplifier model constructed using ADS simulator. The amplifiers are modeled as two fixed voltage sources delivering every one 30 dBm with 50 Ω output resistors. The phase  $\theta$  varying from zero to 90° is added positively to the upper source and negatively to the lower source. The frequency is set variable from 1 GHz to 4 GHz in order to test the outphasing system for  $f_0 = 2$  GHz,  $f_0/2 = 1$  GHz and  $2f_0 = 4$  GHz. The 100 Ω resistor is connected at the input of the combiner to test firstly the outphasing system with a matched Wilkinson combiner.

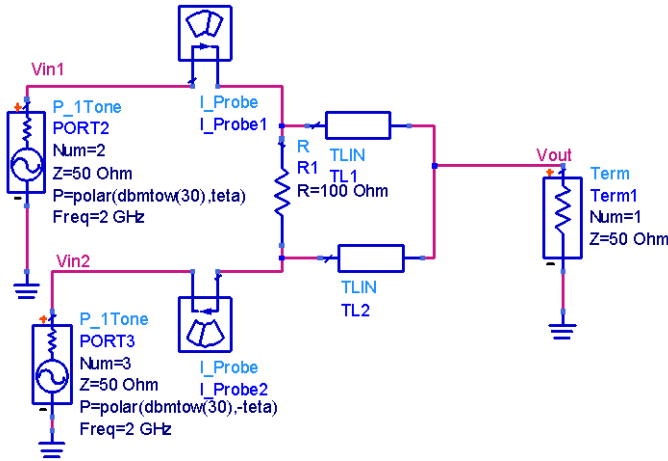


Fig. 3. ADS simulation of the outphasing system.

The simulation of the system is done, and four graphics are extracted from this simulation. Fig. 4 shows the impedance variation at the combiner inputs in function of the signal phase according to the three frequencies. We can see clearly from this figure that the input impedance of the combiner is fixe in function of  $\theta$  for  $f_0$  and equals 50 Ω, while the impedances are no more fixe for  $f_0/2$  and changes dramatically in function of the phase for  $2f_0$ , it starts from 100Ω and decreases having some imaginary components to ends at zero ohm. We can prove by this test that the combiner is matched with the amplifier output impedance only for  $f_0$  where the combiner is designed at this frequency.

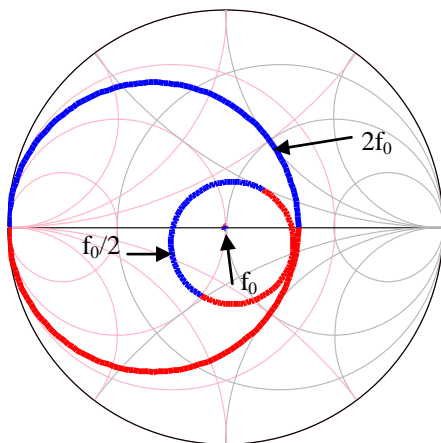


Fig. 4. The matched combiner impedances in function of  $\theta$ .

In fig. 5, the drain current of the amplifiers is presented in function of  $\theta$  for the same three frequencies. This current variation is normal according to the impedance variation at the combiner inputs. Otherwise, and comparing with fig. 4, we can see that the drain current is constant and equals 0.4 A for  $f_0$  when the combiner impedance is fixed at 50Ω for all phases. While this current increases slowly starting from 0.34 A with  $f_0/2$  and increases fastly starting from 0.27 A with  $2f_0$ .

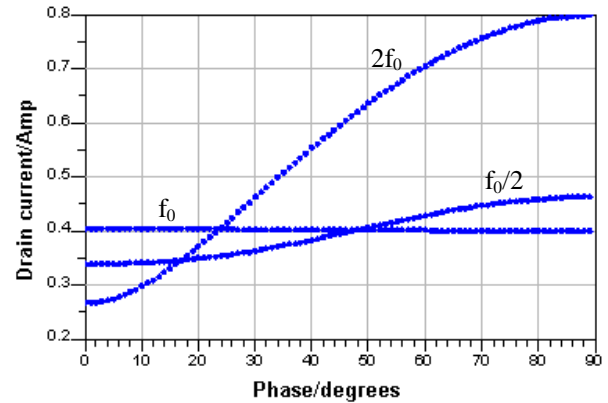


Fig. 5. The amplifiers drain current with a matched combiner.

Fig. 6 represents the graphic of the power efficiency of the outphasing system in function of  $\theta$  for the three different frequencies. We can see clearly that the power efficiency for  $f_0$  starts from 70% when  $\theta = 0^\circ$ , and decreases following equation  $\cos^2\theta$  when the phase increases [5][6]. While with  $f_0/2$  the power efficiency starts with 80% but decrease slightly faster and with  $2f_0$  the efficiency starts with 95% and decreases very fast in function of  $\theta$ . This also happen according to the situation of the amplifiers drain current described in fig. 5.

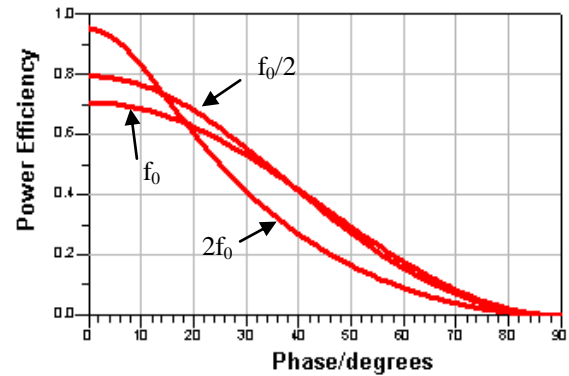


Fig. 6. The power efficiency with the matched combiner.

The linearity of the outphasing system is described in fig. 7. We see in this figure the relationship between the input and the output power. It is observed clearly that excellent linearity is obtained for all frequencies, but the maximum power of 2 watts or 33 dBm is reached only with the frequency of  $f_0$  while 5% of this power is lost with  $f_0/2$  and 10% is lost with  $2f_0$ . Finally, despite of some degradation in some performance when using the outphasing amplifier with a matched Wilkinson combiner for large band frequency, the system is responding well. For best using of this amplifier, the input signal with a frequency band of 10% around  $f_0$  may give better result.

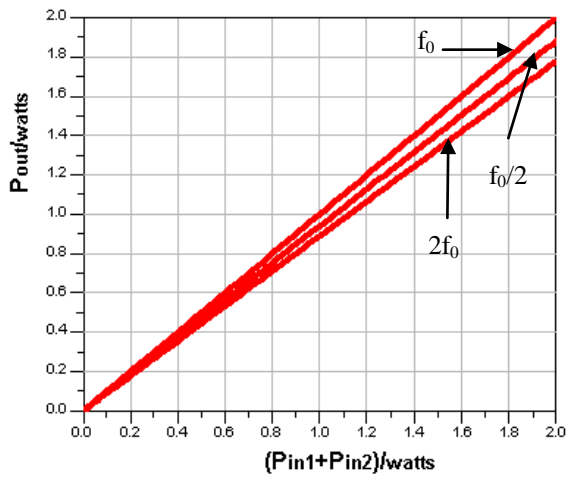


Fig. 7. The system linearity with a Wilkinson matched combiner .

### III. OUTPHASING AMPLIFIER WITH UNMATCHED COMBINER

In this section the outphasing amplifier shown in fig. 3 is tested using an unmatched Wilkinson combiner where the 100  $\Omega$  resistor is disconnected from the inputs of the combiner. The same ADS simulation is done and the same graphics are drawn in function of the phase variation for the same three frequencies.

Fig. 8 shows the combiner input impedances in function of  $\theta$  for the different three frequencies  $f_0$ ,  $f_0/2$  and  $2f_0$ . We can observe that the combiner input impedances varies in function of the phase for all frequencies.

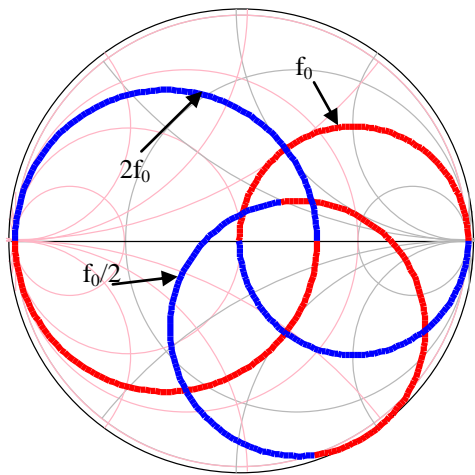


Fig. 8. The unmatched combiner impedances in function of  $\theta$ .

For  $f_0$ , the impedances start with a real 50  $\Omega$  when  $\theta = 0^\circ$  and increase by adding an imaginary part to reach the infinity when  $\theta = 90^\circ$ . For  $f_0/2$ , the impedances change in both the real and imaginary part in function of  $\theta$ . For  $2f_0$ , the impedances start with real 100  $\Omega$  when  $\theta = 0^\circ$  and decrease in real and imaginary part to get zero ohm when  $\theta = 90^\circ$ . It is normal to get this result at  $2f_0$  because the combiner lines seem to be half wavelength at the double of  $f_0$ . If the first quarter wavelength of the lines forms the combiner, the second quarter wavelength behaves as an impedance transformer for this combiner. That why the Smith chart of fig. 9 shows the impedances with  $2f_0$  vary in the opposite direction of the impedances with  $f_0$ .

The drain current variation in function of the signal phase is presented in Fig.9. For the frequency  $f_0$ , the current drop in function of the phase and ends with zero amperes, while with  $f_0/2$  and  $2f_0$ , the current increases producing power efficiency degradation.

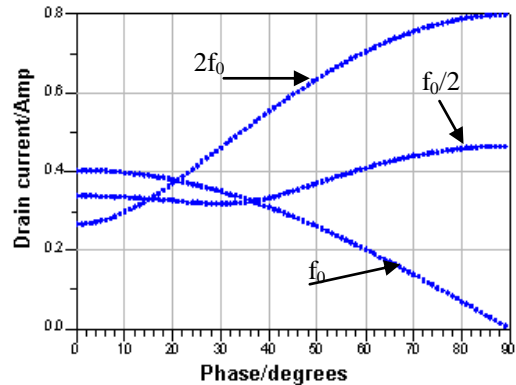


Fig. 9. The amplifiers drain current with the unmatched combiner.

In fig. 10 we represent the graphics of the power efficiency of the outphasing amplification system using the unmatched combiner in function of the signal phase for the same three frequencies. We can observe here that for  $f_0$ , the efficiency starts by about 72% and decreases in function of  $\theta$  following  $\cos\theta$  equation and ending at 0% when the phase becomes  $90^\circ$  [7]. For  $f_0/2$  and  $2f_0$ , the efficiencies start at 80% and 95% but decrease fast in function of  $\theta$ .

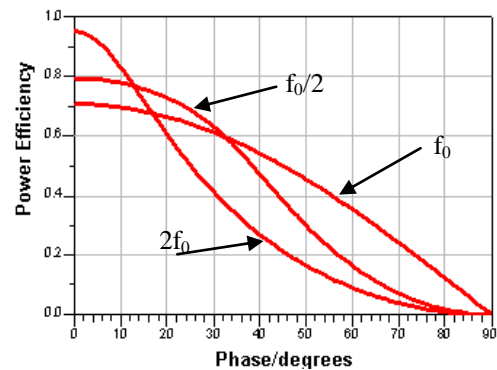


Fig 10 The power efficiency with the unmatched combiner.

Fig. 11 is the last graphic extracted for the outphasing amplifier using unmatched combiner; it represents the signal linearity between the input and the output power. We can observe in this figure that the relationship between  $P_{out}$  and  $P_{in}$  is the same as in fig. 7 for the matched combiner.

Finally, comparing the two systems, the outphasing amplifier with matched combiner and that with unmatched combiner, we can conclude when comparing the results obtained in fig. 6 and in fig. 10 that the power efficiency is better when using an unmatched combiner despite of the reflection coefficient at its inputs. It can be observed also by comparing fig. 9 and fig. 5 the graphics of the amplifiers drain current in function of the phase variation that for  $f_0$ , the drain current is constant with a matched combiner and equals 0.4 A, while with unmatched combiner the drain current drop starting by 0.4A at  $\theta = 0^\circ$  and ends with zero amperes when  $\theta = 90^\circ$ .

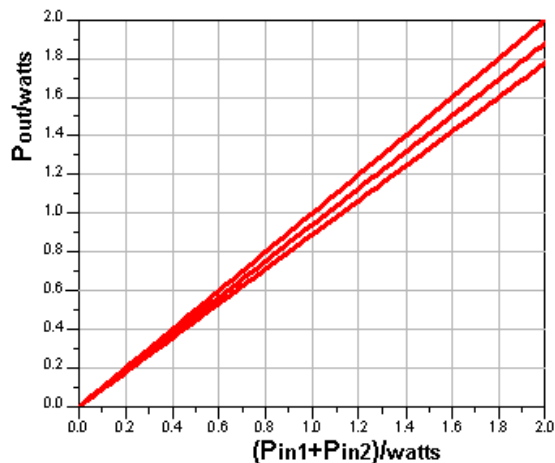


Fig. 11. The system linearity with the unmatched combiner.

#### IV. CONCLUSION

Two systems of outphasing amplifiers are presented and tested using ADS simulation, one using a matched Wilkinson combiner, the second using an unmatched combiner. The examination is done with a band of three frequencies. The different graphics obtained in this study show the performance of every one according to a large frequency band in function of the signal phase varying from zero to  $90^0$ . The graphics were clear to make the comparison between them. We can say that the behaviors of the system using an unmatched Wilkinson combiner reduces the power consumption in function of the phase variation and this leads to obtain better global power efficiency comparing with the matched one. The linearity examination shows no different between the two systems and getting excellent results.

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