THE USE OF A SINGLE SOURCE TO DRIVE A BINARY PEAK POWER MULTIPLIER

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ABSTRACT

The binary power multiplier (BPM) recently proposed by Farkas[1] requires a pair of RF inputs whose phases are set independently. In this note, a method is presented in which a single source may be used to drive a BPM. Phase coding occurs at the source input where the power is low and phase switching is straightforward. There is a loss in energy of around 25% but only a small reduction in peak power.

I. INTRODUCTION

Future TeV linear colliders require sources producing peak power in the 100 megawatt range. The exact power level depends on frequency, but present estimates are around 750 MW at 2.8 GHz[1] (SLAC frequency), 500 MW at 10 GHz[2] and 200 MW at 17 GHz[3]. When additional constraints such as high efficiency, high gain and phase stability are introduced, these powers are beyond the state-of-the-art of present and near-future sources. To circumvent the lack of suitable sources, pulse compression may be used to increase peak power at the expense of pulse length, thus reducing the requirements to technologically feasible levels.

Recently, Farkas proposed an efficient multiple stage pulse compression scheme[1] in which the power is doubled and the pulse length halved at each stage. This scheme is described in detail in Reference 1; briefly, a single stage of the binary power multiplier (BPM) works as follows: the input into each stage consists of two pulse trains coded into time bins, with a phase of either 0° of 180° in each bin. The pulse trains are combined to produce two outputs, each at twice the power and half the duration and properly coded for the next stage. The coding for this process is illustrated schematically in Fig. 1a, where a phase of 0° is denoted by a $-$ and a phase of 180° by a $+$. The power doubling, which is shown in Fig. 1b, occurs in two steps. First, adjacent bins are combined by a 3-dB hybrid coupler. Second, the leading pulse is delayed so that the bins are again adjacent. The peak power multiplication is 2^n for an n-stage device, less any losses due to non-ideal properties.

This pulse compression scheme has been demonstrated at low power using both fundamental mode rectangular and TE_{01} circular waveguide.[3] While the basic validity of the binary pulse multiplication scheme was confirmed, the losses were high (greater than 40% power loss for the two stage BPM). For practical applications, delay lines with acceptable wall losses and 3-dB hybrid couplers with minimal mode conversion and reflection need to be designed. In addition, problems of phase noise need to be studied as the BPM efficiency degrades rapidly with phase jitter.

Because of the high power involved, the coding of the pair of pulses trains which enters the BPM must occur at the input end of the source where the power is low. Consequently, two separate sources are needed to drive a single BPM if it is to operate at maximum efficiency. For testing and development, however, it is desirable to use a single source. This may be done with some decrease in energy efficiency (less than 30%) but little loss in peak power. A description of the single source BPM is presented in the next section, and a summary is given in Section III.

II. A SINGLE SOURCE BPM

To function, a BPM requires only a pair of pulse trains with the proper coding. While in principle one could split the output from a single source and code each independently by introducing a 180° phase shift at appropriate times, the high powers involved preclude such an approach. However, a single source may be used with a 50% loss in energy by coding the input into twice as many time bins as are needed, splitting the output, delaying one of the pulse trains by half the pulse length, then recombining the first half of one pulse with the second half of the other. This process is illustrated in Fig. 2 for a two stage, single source BPM. The final pulse is 1/8th the length of the source output and four times the power. While half the energy is wasted, there is only a small loss in peak power that occurs during the initial splitting and delay.

In fact, with a proper design it is possible to use significantly more than 50% of the pulse. For instance, by splitting a 5-bin output in two and combining the first 80% of one with the last 80% of the other, proper coding for a $\times 4$ BPM can be achieved (see Fig. 3a). This is possible even though the combined pulse trains are not independent, essentially because the coding for a BPM is not unique -- there are many "correct" initial coding sequences for a given multiplication factor. Thus, while there is no guarantee of finding an energy efficient device for multiplication above $\times 4$, we expect at least some improvement over 50%.

Using a semi-systematic trial and error method in which successively longer delays (and thus lower efficiencies) were investigated, $\times 8$ and $\times 16$ BPMs were found with efficiencies of 73% (8/11) and 76% (16/21). The coding for these is shown in Figs. 3b and 3c. It is expected that similar results would be achieved at higher multiplication factors.

While the increase in energy efficiency is an added plus, the main thrust here is that a BPM can be driven with a single source. This will significantly lower the cost, both economically and in terms of manpower, of testing and development of BPMs for practical applications. In addition, even with a 30% energy loss the single-source BPM is only slightly less efficient than SLED[4], the pulse compression scheme currently in use at the Stanford linear accelerator. Moreover, it can produce larger compression ratios (SLED efficiency peaks at about 3:1) and a significantly flatter output pulse.[1] Thus, in applications where efficiency is not a premium the relative simplicity of a single-source BPM makes it an attractive alternative to the two-source BPM.

III. SUMMARY

A method is illustrated for driving a BPM using a single source. As with the two-source BPM, coding occurs at the source input where the power is low. While there is an additional loss of energy between 20% and 30% over a two-source BPM for $\times 4$, $\times 8$, and $\times 16$ multiplication, there is only a small reduction in power associated with the initial splitting and delay of the source output.

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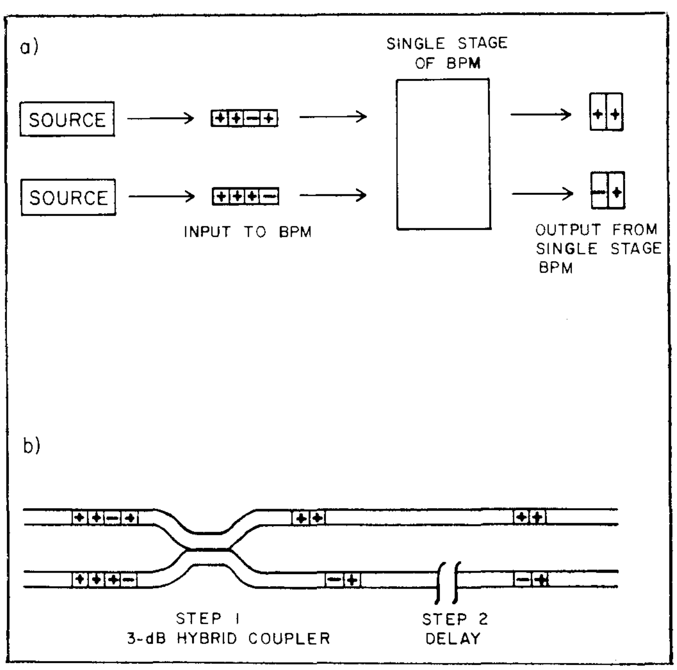
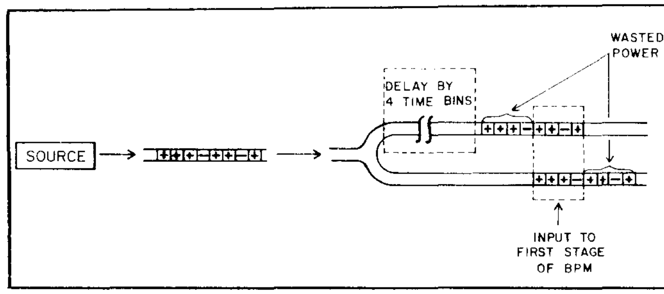
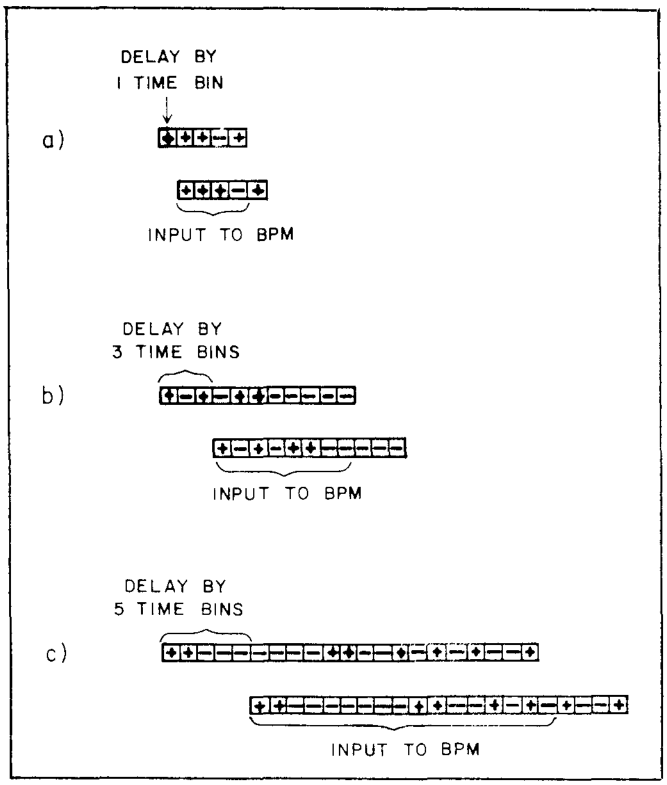


1. (a) Coding for a single stage binary power multiplier. The time bins are coded according to phase: − represents 0° and + represents 180°. On output, the pulse length is halved and the power doubled. (b) Schematic of a single stage BPM.



2. Preparation of a single source for input into a three stage BPM. Note that the overlap region has the same coding as in Fig. 1a. This method works for any number of stages, as the first and second half of a pulse may be coded independently.



3. Energy efficient coding for a single source: a) ×4 multiplication; b) ×8 multiplication; c) ×16 multiplication.