Power Amplifier Phase (Power) Combining

**General:** When two signals of identical phase and amplitude are fed to a 180 – degree hybrid or “Magic T” combiner, the two signals are summed in one of the O/P ports and cancelled in the other output port. Phase matching is more critical than amplitude (gain) matching. Initial differences at a given frequency, mid-band for example can be balanced out by inserting an adjustable phase shifter in series with one of the power amplifiers, and by adjusting the input attenuator of the respective amplifiers. The basic combining circuit is shown in the figure below. The RF input signal is fed to a 180 – degree divider (or splitter) to form two incoherent equal in amplitude signals. The two signals are amplified by the respective amplifiers and then re-combined in another 180 – degree phase combiner such as a hybrid or magic “T” or a variable ratio combiner. The phase shifter in series with the input to one of the power amplifiers is used in conjunction with the input attenuator of the power amplifier to balance the phase and amplitude of the two power amplifier output signals. The two signals are summed at the RF output port and any small unbalance in power is absorbed by the load termination. This unbalance is observed as a null reading on the power meter, which monitors the power to the dummy termination. A common variable attenuator is included in the input line for adjustment of the combined RF output level.

**Figure 1. Block Diagram, Basic Power Combiner Circuit**

**Description:** The CPI series of power/phase combiners cover the frequency ranges representative of the TWT amplifiers used in the combining network. The power/phase combiner and the respective amplifiers that are used in the combining system are as follows: VZL2780C1 (using 2 VZL6943J2 TWTA’s), VZS/C2780C1 (using 2 VZS/C6963J2 TWTA’s), and VZM2780C1 (using 2 VZM6993J4 TWTA’s).
All of the components described herein making up the combiner network (excluding the TWTA’s) are packaged in a 19-inch rack mountable enclosure thus allowing for installation in a standard rack/cabinet. As a standard feature the TWTA’s come equipped with chassis slides necessary for installation into the same 19-inch rack (see Figure 2).

*Figure 2 – Recommended installation*

Along with the TWTA RF source specified herein, the series of power/phase combiners consist of a coaxial input divider network, phase shifter, and a front panel module. The front panel combiner module comes equipped with the following features:
- Voltage controlled step attenuator.
- Front panel phase adjustment
- Excessive RF load power alarm.
- RF sample ports for O/P power and load.
- LCD display giving constant power monitor of O/P power and load.
- O/P power in dBw and in Watts.
- Local and remote control.
- Complete set of installation and operating manuals including list of replaceable parts.

Please see Figure 3 below for a diagram of a typical power combiner module front panel.

**Figure 3: Power Combiner Module Front Panel**

It is understood that due to the inherent properties of the phase combiner, the power/phase combining network will ensure that the performance in most instances will exceed that of the individual TWTA. However, since measurements of some of the parameters have not been taken, the performance of the “SYSTEM” requires testing over the frequency ranges specified and thus only typical performance specifications are identified below.

**500-Watt Power/Phase “Combined System” Electrical Specification**

- **Frequency**
  - VZL2780C1: 1.0 – 2.5 GHz
  - VZS/C2780C1: 2.0 – 8.0 GHz
  - VZM2780C1: 8.0 – 18.0 GHz

- **Output power**
  - TWT Flange: 300 Watts typical
  - “RF Combining System”: 500 Watts minimum (see Figure 4)

- **Instantaneous Bandwidth**
  - VZL2780C1: 1.5 GHz
  - VZS/C2780C1: 6.0 GHz
  - VZM2780C1: 10.0 GHz

- **Gain**
  - 50 dB typical at rated power

- **RF attenuator adjust range**
  - 0 to 20 dB

- **Gain stability**
  - Typically ±0.2 dB max.

- **Small signal gain variation**
  - Typically 12 dB peak – to – peak

- **Input VSWR**
  - 2.5:1 max, 1.5 max with optional input isolator
- Output VSWR: 2.5:1 typical
- Load VSWR: Full spec. Compliance
- Operation w/o damage: 1.5 max.
- Continuous operation: Any value
- Harmonic output: 2.0:1 max. For full O/P power
- Primary power: -10dBc typical at lower band edge, decreasing to –15dBc typical at upper band edge.
- Power factor: 220 – 240 ±10%, single phase 47 – 63 Hz
- Power consumption: 0.95 min. (meets requirements of EN60555-2, total harmonic distortion)
- Inrush current: VZM2780C1 5.4 kVA typical 6.5 kVA max.
- VZS/C2780C1 5.4 kVA typical 6.5 kVA max.
- VZM2780C1 3.5 kVA typical 4.2 kVA max
- 200% maximum.

Figure 4: Typical Measured O/P Power versus Frequency for the VZL2780C1, VZS/C2780C1, and VZM2780C1 series of TWT amplifiers.

![VZL2780C1 (1.0 - 2.5 GHz)](image)

Figure 4(a): VZL2780C1 (1.0-2.5GHz, 500-Watts) O/P Power versus Frequency
Figure 4(b): VZS/C2780C1 (2.0-8.0 GHz) O/P Power versus Frequency

Figure 4(c): VZM2780C1 (7.5-18.0 GHz) O/P Power versus Frequency
NOTES:

1. The RF and electrical performance of the system is understood to be the performance of four CPI TWT amplifiers power/phase combined with a VZL2780C1, VZS/C2780C1 or VZM2780C1 power/phase combiner.

2. In the event of a fault in one of the power amplifiers, the hybrid or “Magic Tee” combiner will divide the output of the surviving power amplifier equally between the termination port and the RF output port. The resulting output power is about 6 dB below the initial combined output.

* Customer specified RF connections will be used whenever mechanically/electrically possible.