Using High-Directivity Couplers in Isolatorless Cellular Phone PA Control

ABSTRACT:

This article outlines the use of High-Directivity Couplers in Cellular handsets. Benefits can include increased talk-time, minimized insertion loss between the PA and the antenna and can also remove the need for an isolator.

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Directional couplers and power measurements

In RF applications Directional couplers are used to separate signals based on propagation direction. The wave induced in the auxiliary arm (coupling line) is proportional to the forward wave traveling in the transmission system (main line). The ratio of the induced power to the input power is known as the **coupling factor**.

Directivity is defined as the difference in dB of the power output at a coupled port, when power is transmitted in the desired direction, to the power output at the same coupled port when the same amount of power is transmitted in the opposite direction

$$\textbf{Coupling factor} = 10 \log \frac{P_2}{P_1},$$

where P_1 is the input power, and P_2 is the coupled power.

$$\textbf{Directivity} = 10 \log \frac{P_2}{P_{2R}},$$

where P_2 is the coupled power for the forward signal, and P_{2R} is the coupled power for the reverse signal.

Directivity (dB) = Isolation (dB) – Coupling (dB)

Finite isolation is the reason for limited directivity.

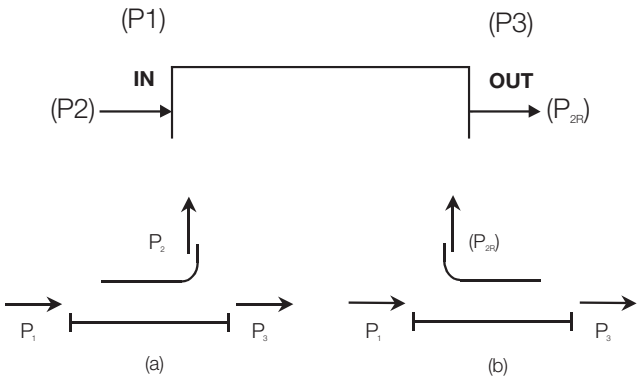


Figure 1. Schematics of (a) forward, (b) reverse directional coupler [1].

Power meters measure power in the transmission line by measuring the output of a directional coupler at the coupling port. This output is affected by the coupling factor.

The power reflected in the main line will produce a measurement error (directivity error).

Power measurement accuracy can be improved by eliminating the reflected signal, or by using a **High Directivity** Coupler.

Power control in a mobile phone

Mobile phones receive and transmit signals through an antenna connected to RF circuitry.

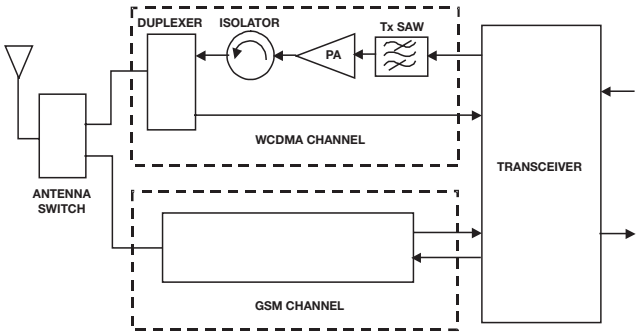


Figure 2.
Basic GSM + 3G Radio Diagram

In the 3G band, WCDMA modulation results in a variable signal amplitude typically delivering a peak to average output power in excess of 3 dB, spread over a channel bandwidth of 5MHz shared among up to 256 users. The output power level of the mobile handset is tuned by the base station which requires that uplink signals from all mobiles transmitting in the same channel be received at a power level within a 1dB accuracy. Failure to meet this requirement results in interrupted calls for the weakest signals hence a poor level of service perception from the users.

By contrast, the GSM band uses the TDMA standard with GMSK type signal modulation where the mobile station is the only user in a given time slot and channel. This means that the impact of poor power control on the other users of the network is negligible.

Implementation of High-Directivity Couplers

Any changes in the close environment of the antenna may result in mismatch and under certain circumstances increased reflected power. The maximum VSWR which we will consider is 6:1, which is the worst case when the antenna is not extended.

In order to transmit the forward signal and reject any reverse signal coming from the antenna because of mismatch, Isolators are inserted between the PA output and the antenna. Input and output impedances are 50 Ohm.

There is always a strong incentive to eliminate the Isolator for the following reasons:

- Isolators are thick, bulky and take up valuable PCB area.
- Isolators are expensive.
- Isolators introduce a high Insertion Loss (typically above 0.7dB).
- Isolators are temperature sensitive and exhibit ageing.

Coupler solutions have been developed to monitor the PA output signal in power control applications and this technique can be adapted to monitor both the transmitted power and the reflected power resulting from the antenna mismatch.

The " Vi/Vr " method consists in monitoring both the incident and the reflected power. When excessive VSWR is detected at the antenna, the output power is reduced to a value as close as possible to the target power.

Implementation of the Vi / Vr concept with standard directivity couplers (below 10dB) is impractical because (1) It requires 1 coupler for each direction (2) Control accuracy is poor (3) Cost and complexity are high.

Couplers with high directivity (above 15dB) and symmetrical performance are critical for the precision monitoring of Incident and Reflected power signals. They increase the accuracy of the power control circuit and allow the use of a single coupler.

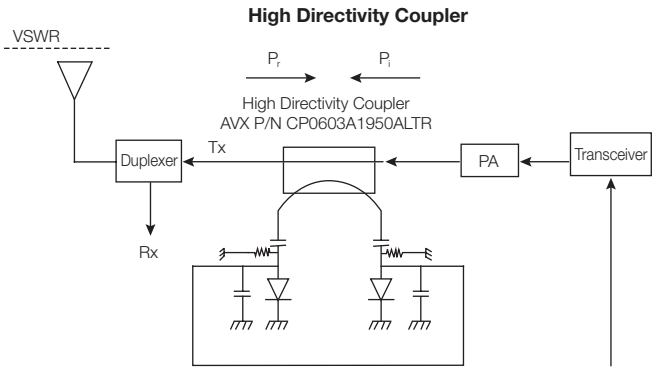


Figure 3.
Power control with a high directivity coupler

A single miniature AVX wideband High Directivity Coupler detects both Vi and Vr allowing the measured **ratio** between incident and reflected power to be used for precisely controlling the output power.

It is important to note that this ratio is independent of the coupling factor accuracy (as long as the signal to the detector is sufficient). It is however strongly dependant on Directivity as illustrated in the table below.

Table. Power Control Accuracy.

Coupler Directivity	Power Control Accuracy
20dB	±0.044dB
15dB	±0.14dB
10dB	±0.46dB
8dB	±0.75dB
6dB	±1.25dB

AVX High Directivity Couplers

The **AVX High Directivity Couplers** were developed to meet the stringent requirements of this application.

High directivity in a small physical size is difficult to achieve. The coupler directivity can be optimized by balancing contributions from electric and magnetic fields as well as accurately applying phase calculations.

AVX uses semiconductor manufacturing techniques: metal sputtering, lithography and plating. This enables precise geometry of metal conductors.

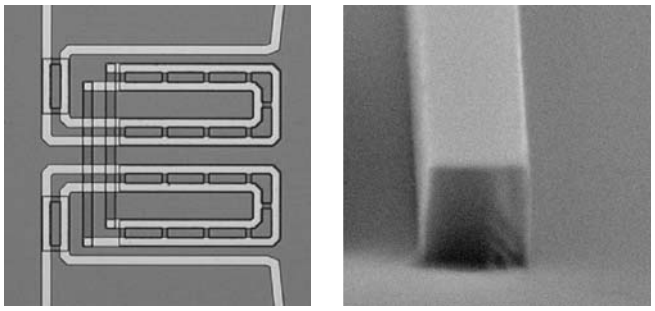


Figure 4.
Fine metal elements in the AVX coupler

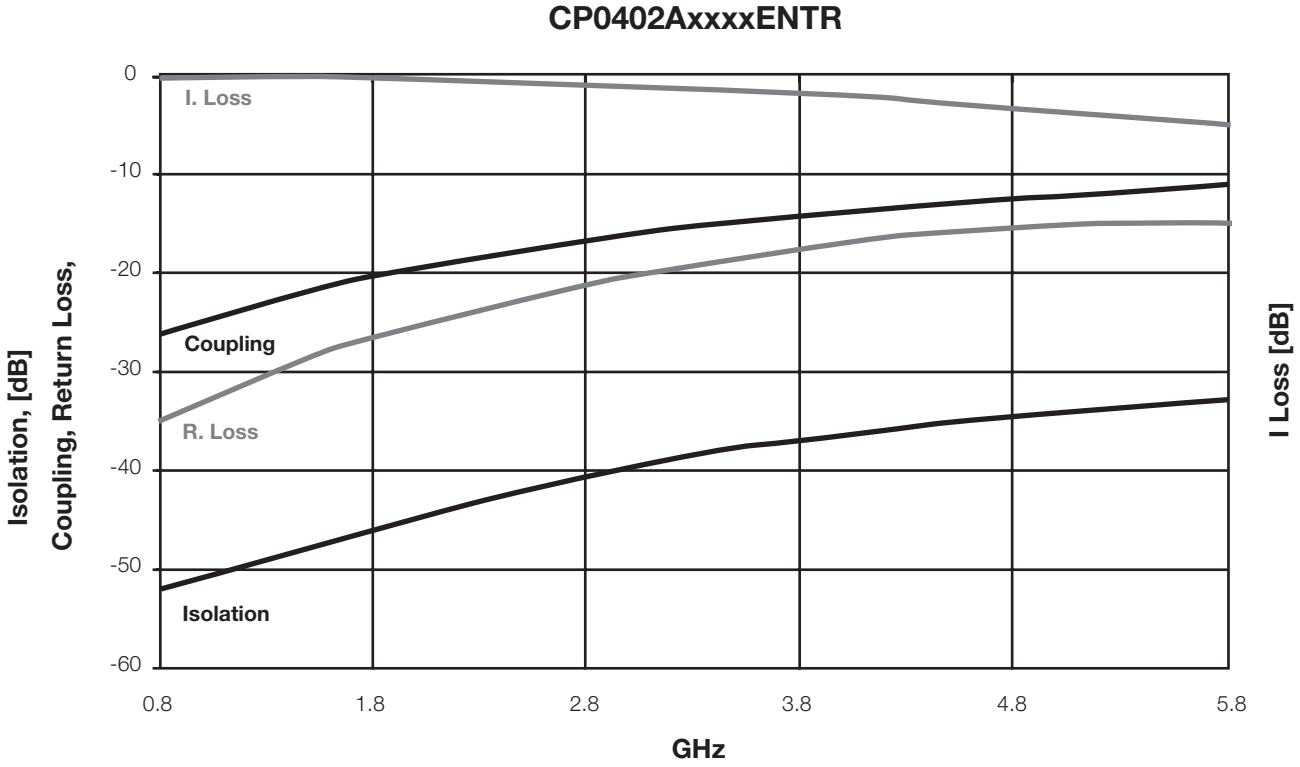
The **CP0402** and **CP0603** range of **AVX High Directivity Couplers** is based on thin-film multilayer technology. This Technology provides a miniature part with excellent high-frequency performance and rugged construction for reliable automatic assembly.

The couplers are offered in a wide range of frequency bands and intermediate coupling values are readily available.

Several High Directivity Coupler types are available with the following characteristics:

- Frequency range 400MHz to over 6GHz
- Coupling factor range from 8.5dB to 27.5dB @ 1950MHz
- Low I. Loss (0.2dB)
- High Directivity (over 20dB)
- 0402 and 0603 Package sizes.

Typical Electrical Performance of an AVX High Directivity Coupler



Summary

Implementing the Output Power Control technique described offers the following benefits:

- Cellular handset talk time is increased.
- PA output power is accurately controlled.
- An isolator is no longer required.
- Cost is reduced
- Insertion loss between the PA and the antenna is minimized.
- PCB height and size are reduced.

Reference

1. S. F. Adam. Microwave Theory and Applications. Adam Microwave Consulting Inc., Los Altos, CA, 1992.

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