

Introduction

Radio frequency couplers are found in a wide variety of applications within transmission systems of varying classes. These components may be used as the heart of a transmission line power measurement system, or as a means of extracting a sample of the energy present within the transmission line in order to perform spectrum, modulation, or other types of analysis.

RF couplers generally belong to one of two classes, as determined by the nature of their interaction with the transmission line structure. **Non-directional couplers** provide a sample of the potential (voltage) that exists between the inner and outer conductors of the transmission line. Couplers within this class are not able to discern between the forward and reflected traveling waves within the transmission line. **Directional couplers** form the other class of RF couplers, and these components are capable of providing samples of either the forward or reflected traveling wave, depending upon their orientation within the transmission structure.

In this brief note, we will discuss some of the characteristics, applications, and limitations of both classes of these components.

Non-Directional Couplers

The most common implementation of a non-directional coupler involves the placement of a probe into the transmission line, such that the area associated with the end of the probe forms a capacitor with its projected area on the transmission line center conductor. At the plane where the probe crosses the outer conductor of the transmission line, a lumped capacitor (usually a discoidal type) is placed between the probe and the outer conductor. The combination of this shunt capacitor and the capacitor formed between the probe and the center conductor form a voltage divider for the voltage on the transmission line. Selection of the values of these capacitors determines the coupling factor for the coupler.

Following are some key characteristics and applications for non-directional couplers:

- **Frequency Response**
Non-directional couplers, due to their inherently simple electrical configuration tend to be fairly broadband components when compared to their directional cousins.
- **Sensitivity to Transmission Line Position**
Since the non-directional coupler is coupled to only the electric field within the transmission line, these components are very sensitive to position on the transmission line. The interaction between the forward and reflected traveling wave components, when the transmission line is terminated by a load with impedance that is different from its characteristic impedance, will result in a standing wave within the transmission line. The non-directional coupler will follow the peaks and nulls of the standing wave pattern.
- **Application**
When the non-directional coupler is used in a well – matched environment, as evidenced by a small standing wave characteristic, these components may be used in broadband power measurement applications. In these applications, a power detector, selected for the appropriate input level and dynamic range is placed at the output of the coupler. In many cases, this approach may be implemented by placement of the non-directional coupler at the input to a high quality RF termination load. As mentioned above, these couplers may also be used to provide waveform samples for analysis instruments. In these applications, line position sensitivity may not be a limiting factor, as most analysis instruments provide sufficient input dynamic range to overcome the variation in output voltage associated with varying line position.

Directional Couplers

The most important defining characteristic of these components is their ability to couple to either the forward or reflected traveling wave. This capability is the result of coupling to both the electric and magnetic fields within the transmission line structure. A perfectly balanced directional coupler design results in an output of zero when the coupler is oriented for the reflected traveling wave, with the transmission line terminated in its characteristic impedance. (zero mismatch) Under this condition, the samples resulting from the electric field and magnetic field are equal. In practice, this is difficult to achieve, particularly for a structure that must operate over a relatively wide frequency range.

Following are some key characteristics and applications for directional couplers:

- **Frequency Response**
Directional couplers are generally narrower bandwidth components as compared to their non-directional cousins. This is the result of the additional reactive components that are required to form the magnetic field coupling network necessary in order to provide a directional response.
- **Sensitivity to Transmission Line Position** Since the directional coupler provides coupling to both the electric and magnetic fields within the transmission line structure, and the voltage and current waveforms are offset by 90° in the transmission line under mismatched conditions, the directional coupler is relatively insensitive to transmission line position. This insensitivity is directly related to the degree of directionality (directivity) of the coupler. Note that the directional coupler directivity is a frequency dependent quantity.
- **Application**
Directional couplers are widely used as the main link to the transmission line for radio frequency power measurement applications. In these applications, an appropriate power detector is connected to the directional coupler sidearm. The ability to determine both the forward and reflected power in the transmission line provides the capability to determine the degree to which the transmission line and the antenna or other load is mismatched (VSWR or Return Loss).

In this note, we have discussed the characteristics of the two most common types of transmission line couplers. Familiarity with these defining attributes will result in the ability to make good choices as these components are applied.