Classification and principal analysis of couplers

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Abstract. Microwave Technology is one of the most of important technologies in history. Microwave technology is developing faster and faster. As we can see, it is very common in our daily life. Microwave technology are used for phone, televisions, security checks and so on, which are all very important in our life. Televisions and mobile phones have become essential devices in every home. It in addition to bring people a relax and cheerful mood, but also is an important communication tool for would news and media opinion. Microwave technology has made a great contribution to our high quality of life and safe travel. With the development of society, microwave will be more and more widely used by people. This paper describes the principle and properties of couplers. The classification of couplers and the principle of couplers are studied by referring to a large number of literatures.

1. Introduction
In our life, sometimes signals need to be isolated, separated and mixed, such as power monitoring, source output amplitude stabilization, source isolated, transmission and reflection frequency sweep testing, etc. So, at this point people can use directional couples. Firstly, directional couples can be used for power synthesis. Multichannel power can be integrated, and the output of each channel will contain multiple frequency components. Besides that, directional couples can be used for measurement of anti-interference of receivers. The coupling end of the directional coupler can input a neighboring interference signal to the receiver. A through-end synthesis tester connected to a directional coupler can test the anti-interference performance of the receiver. In addition, directional couples can be used for signal sampling and monitoring. Finally, directional couples can be used for online measurement of power. The world's first directional coupler was invented in 1944 by a designer named H.A.Wheeler. At that time, due to the influence of environmental conditions, technology and other factors, he used a pair of cylinders with one-quarter of the central frequency wavelength to realize the energy coupling between electric and magnetic fields. However, in the end, this method could only realize the bandwidth of one octave. With the development of technology and science, people have higher and higher requirements for microwave circuits and systems, such as miniaturization, lightweight and reliable performance. So slowly ribbon lines and microstrip lines appear. Then due to the need for coplanar waveguides, slot lines and other microwave integrated transmission lines. Thus, a variety of transmission line direction couplers came into being. This paper mainly focuses on the working principle, application and characteristics of different directional couplers. [6] in the current age, to make a device or a product, coupling is essential. With the improvement of the particularity of goods in the society, the requirements of couplers will be higher and higher. Therefore, further research on couplers is very necessary.
2. Classification of directional couplers

There are many kinds of directional couplers and people can classify them from many aspects. They can categorize in five ways. If classified by output line type, it can be divided into four types: waveguide directional coupler, coaxial coupler, strip line directional coupler and microstrip line directional coupler. It can also be classified by coupling. It can be divided into four categories, which are single hole coupling modes, multi-space coupling mode, continuous coupling mode and parallel line coupling mode respectively. In addition, people can also categorize by direction of output, namely, co-coupling and reverse coupling. Besides that, directional couplers can also be classified by the output phase. It can be classified as 90-degree orientation and 180-degree orientation. Finally, people can classify directional couplers by coupling strength, which are strong coupling, medium coupling and weak coupling.

3. Indicator of a directional coupler

3.1. Coupling degree

Coupling is a measure of the degree of association between modules. The strength of the coupling depends on the complexity of the module’s indirect interface, how the module is invoked, and how much data is transmitted through the interface. Each module has a dependency relationship which can be called coupling degree. Therefore, the more connections between modules, the stronger coupling. So, it can be represented as:

$$A = 10 \log\left(\frac{|u_1|^2/|u_1|^2}{|u_2|^2/|u_2|^2}\right)$$  \hspace{1cm} (1)

The coupling degree can be divided into 7 categories. The coupling is arranged from high to low.[4]

3.2. Classification of couplers

3.2.1. Content coupling. When data from one module is modified or manipulated by another or when one module is transferred to another module through an abnormal method. This is content coupling. Content is the highest degree of coupling and should not use it.

3.2.2. Common coupling. Multiple modules reference the same data. This is called common coupling. In a structure with a lot of common coupling, it is different to determine which module assigns a global value.

3.2.3. External coupling. A set of modules all access a control signal passed by a module, information about the global variable is not passed through the parameter table. It is called external coupling.

3.2.4. Control coupling. One module transmits control signals to another, and the receiving module responds appropriately according to the values. This is control coupling.

3.2.5. Mark coupling. One module passes a common parameter to the other two. There is a tag coupling between the two modules that receive the parameter.

3.2.6. Data coupling. Modules pass data to each other through parameters, which is called data coupling, this kind of data coupling generally exists in the system in order to accomplish some functions. However, this coupling mode is the lowest form of coupling.

3.2.7. Indirect coupling. There is no direct relationship between the two modules, and the connection between the two modules is realized through the called of the main module.
3.3. Isolation of coupler
The coupling degree is defined as the ratio of input power P1 at the input end to output power P2 at the coupling end. Coupling degree is a design index. Therefore, it is selected based on usage requirement. It can represent as:

\[ C = 10 \log \frac{P_1}{P_2} \]  

(2)

If the scattering parameter is used to describe the coupling degree. It is shown in as follow:

\[ D = 10 \log \left( \frac{|S_{21}|^2}{|S_{22}|^2} \right) = 20 \log \frac{1}{|S_{21}|} \]  

(3)

The ratio of output power at the coupling end P3 to output power at the isolation end P2, which can be used to represent isolation performance. It can represent as: [5]

\[ E = 10 \log \frac{P_4}{P_2} = D - A \]  

(4)

4. Input standing wave ratio
When the incident wave and the reflected wave have the same phase, the voltage amplitudes are added together and are called the wave belly. In contrast, when the incident wave and the reflected wave have opposite phases, the voltage amplitude is reduced to the minimum voltage amplitude, which is called a trough. The standing wave ratio is the ratio of the amplitude of the wave’s belly voltage to the amplitude of the trough voltage.[3] Suppose the scattering parameter of network is S. the equation 5 as shown as follow:

\[ \rho = \frac{1 + |S|}{1 - |S|} \]  

(5)

5. Waveguide matches double T
T-joints of rectangular waveguides are divided into two types: E-plane T-junction and H-plane T-junction.

5.1. E-plane T-junction
E-plane T-junction acts as a waveguide or coaxial microwave transmission line, when transmitting power, it is sometimes necessary to send the transmitted power separately to several branches. The power distributor will then be used, which requires the required proportional allocation of high frequency energy and good match to the waveguide branch connector. It is shown in as follow:

![Figure 1 E-plane T-junction](image-url)
E-plane T-junction is where the branched waveguide lies in the plane of the electric field vector in the main waveguide. The structure is also symmetric. It is also a reciprocal component. The branch waveguide of the port 1 plane branch is located on the wide wall of the main waveguide surface 1. The branch plane is parallel to the electric field plane of the main mode TE10 wave in the main waveguide surface 2.

It is assumed that the effects of higher order waves are ignored in the branching region of the waveguide. The transmission of TE10 wave is discussed here and its working principle is introduced. When TE10 waves are input from port 1 of the main waveguide, there are energy outputs at port 2 and port 3. When TE10 waves are input from port 2 of the main waveguide, there are energy outputs at port 1 and port 3. When TE10 waves are input from port 3 of the main waveguide, if the load on port 1 and port 2 is equal and exactly matched, then port 1 and port 2 output equal amplitude inverse TE10 waves. When TE10 waves are non inverting input from port 1 and port 2 of the main waveguide, then there is a differential signal output at port 3. If the input is going in the same direction, then the output signal of port 3 is 0, which means there is no signal. If things are different, the input is going in the different direction, then there is signal will output from port 3. [2]

5.2. H-plane T-junction

H-plane T-junction is where the branched waveguide lies in the plane of the main waveguide’s magnetic vector. The structure is also symmetric. It is shown in as follow:

![Figure 2 H-plane T-junction](image)

The waveguide is located on a narrow wall of the main waveguide. The branch plane is parallel to the magnetic field plane of the main mode TE10 wave in the main waveguide. As Figure 2 shown, this is shaped like T, so it is called H-plane T-junction.

It is assumed that effects of higher order waves are ignored in the branching region of the waveguide and its working principle will be introduced. When the signal is input from port 1, port 2 and port 3 have outputs. But it does not have to be constant. When the signal is input from port 2, port 1 and port 3 have outputs. When the signal is input from port 3, the port 1 and port 2 output are output with equal amplitude and same phase. When the signal is input from the same amplitude and phase of port 1 and port 2, there is output at port 3. When the signal is input from port 1 and port 2 with equal amplitude with inverse phase. There is no signal at port 3. The other two cases are the opposite of the E-plane T-junction branch. When the waveguide branched symmetric central plane, port 3 has a maximum output power. However, when the symmetric central plane of the waveguide branch is in the position of the electric field node, port 3 has no signal output. Therefore, the equivalent circuit of H-plane T-junction is a transmission line segment containing parallel branches.[1]
6. Conclusion
To sum up, couplers are common in our lives. There are many circuits that require it such as switching circuit, logic circuit and high regulator circuit, etc. with the development of technology, the variety of couplers is increasing, which means it can do more and more. In addition, couplers have many parameters. People can solve these by the corresponding formula. In this paper, the principle of the couplers, such as the coupling degree, is analyzed. Beyond that, for waveguide matching double T which can be applied to a lot of different places. For the E-plane T-junction, when changing the position of the short-circuit piston, which can change the jX value of the series reactance. Therefore, E-plane T-junction combined with the terminal short-circuit load can adjust the main waveguide load matching. It can be used for power matcher. As for H-plane T-junction, it also can be used for power matcher. It can be combined with the terminal short-circuit load to adjust main waveguide load matching.

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