Development and Research of a Transmission and Receive Polarization Isolation Duplexer

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Abstract. Spatial segregation by enhancing the distance and time isolation by reducing the duty cycle are ways to achieve isolation between the receive and transmission antennas in RF front-end of wireless systems. More and more systems tend to share the same antenna feed network, which needs a transmission and receive isolation duplexer to ensure the sharing of one antenna and sufficient T/R isolation. In this paper, we conclude the characteristics of different sorts of traditional duplexer, declare the development and application of the quasi-optical T/R polarization isolation duplexers which worked with same frequency during high frequency band, and consider the relationship between the electromagnetic propagation principle and metal fences of different shapes about those duplexer. In addition, we discussed the application perspective of designing the T/R polarization isolation duplexers based on meta-materials in the future.

Introduction

The transmission and receive of wireless signals needs antennas. More and more applications require the transmitter and receiver worked in the same time to improve efficiency that concludes many methods which could be utilized to reach a compatible of the both two in this technique area, of which, the most important ways are the spatial segregation by enhancing the distance and the time isolation by reducing the duty cycle. In these days, the transmitter and receiver use the same feed network, which means using the same antenna to transmit and receive, is commonly used in more and more applications. That would avoid the use of two feed networks, which is a simplify of structure, owns a low costs, and ensures the uniformity of transmit and receive antenna. The antenna need to be connected to both transmitter and receiver to realize the sharing of them. While the output power of transmitter is much larger than the burning power of receiver, which makes the main problem of sharing one feed network for transmitter and receiver is to make sure the receiver is normally worked and not be burned down when it's in the transmit state. Which means the T/R isolation, as shown in Fig.1.

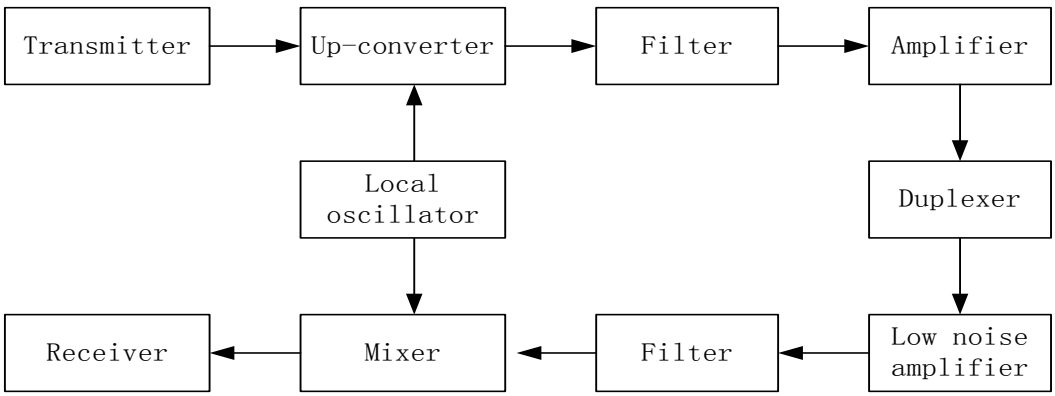

Fig.1. the principle block diagram of RF front-end in wireless devices

The development of traditional T/R isolation duplexer

The T/R isolation plays an important role of RF front-end in wireless communication. Various duplexers existed in the front-end of wireless communication systems. Just like waveguide duplexer, coaxial duplexer, dielectric duplexer, Surface Acoustic Wave duplexer, microwave duplexer, etc. Each of them owns superiority and drawbacks simultaneously.

The waveguide duplexer [1] has the longest time and is the most mature applied in communication filed. The center frequency could reach 100 GHz in practical application. Its biggest advantage is the low loss, however, it bears big volume, high cost, and difficult resonance.

The volume of coaxial duplexer [2] is far less than that of the waveguide duplexer. As electromagnetic is all closed in the coaxial cavity, the resonant circuit has a low loss and its quality factor could reach several thousand.

It also of high stability, shielding good, and easy to ensure the consistency of its production process. If we made it in a spiral filter, it could reduce its size, but decline its quality factor Q at the same time. Which makes a lower Q value of this spiral structure than that one of coaxial structure.

The dielectric resonator [3] is formed by the repeated total reflection of electromagnetic wave inside of the medium. Duplexers made by it could realize miniaturization, however, its high cost hampered its application.

In the early 1970s, the dielectric filter is widely used in the microwave communication field. In the 1980s, after car phones and cellular phones appeared, the dielectric filter began to use in mobile communications, however, it hasn't been widely used so far as its high cost which made it too hard to realize volume production.

Duplexers composed by SAW filter [4] complete their filtering function by the convert of electrical signals and sound signals, also by the transmission processing of sound signals.

Which can achieve the frequency characteristics in any precision. Its good performance and small volume fit to the demand of device miniaturization and high performance. While it's large loss and low support power in high frequency makes it mainly used in the mobile communication terminal of higher miniaturization requirement.

Microwave duplexer [5], because of its low cost, small size and high frequency, attracts a high degree of attention. However low quality factor and large loss are also its inherent drawback. Which makes it used only in the systems with low requirements, thus we always use waveguide and coaxial duplexer in the systems with higher requirements.

In the design of traditional duplexer, we always consider a duplexer as a three port network which connects transmitter to the port of transmit antenna.

Also the receiver is connected to receive antenna via low loss transport channel. While the channel between transmitter and receiver provides high isolation.

In [6], based on similar principles, a filter works in 1880 MHz is between the transmitters and transmit antenna. Also a filter works in 1960 MHz is between the receivers and receive antenna. These two filters are coupled through a quarter-wavelength line between the transmitter and receiver to realize isolation. The insert loss is 2 dB, and the isolation is larger than 45 dB during the frequency band in the whole isolation system.

The application and research of quasi-optical T/R polarization isolation duplexers

As the more and more widely applied THz electromagnetic wave has a millimeter wavelength or even shorter, it is too hard to design traditional duplexer with filter principles. In addition, considering its tiny size, the handling precision requirement is very high, which makes the processing errors that could be neglected in the centimeter wave band may lead to an unable working for the devices in THz band.

With the spreading of applications in THz band, it is widely applied that designing duplexers based on quasi-optical principles and transforming by polarization methods to deal with the T/R isolation in the same frequency.

Recently, variety of quasi-optical grids devices has been applied in more and more microwave devices, such as oscillator, amplifier, mixer, phase shifter, frequency multiplier, switch, etc. Also the research about applying quasi-optical grids in power combiner devices is in studying. In a quasi-optical transmission system, always the output port of transceiver is a quasi-optical power amplifier. As shown in Fig.2. We can see that the four plates arranged in series in the right-most could achieve a polarization conversion function from linear polarization to circular polarization. Each plate is composed by placing the metal grids in 45 degree on a media substrate.

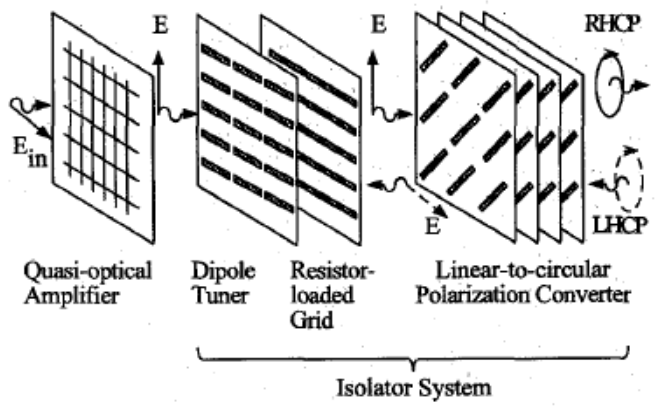

Fig.2. the structure of metal grids polarization converters

The outlook of T/R metamaterials polarization isolation diplexer

In recent years, research on metamaterials suggests that it could achieve a permittivity and permeability within a certain range that conventional materials cannot be achieved.

Thereby it could effectively controlling the propagation characteristics of electromagnetic wave. Also anisotropic is an important electromagnetic characteristics of metamaterials. Most of the permittivity and permeability of the artificial medium structure can be expressed in the form of the tensor, and therefore the material consisting from these structures can have different electromagnetic responses of electromagnetic waves in the respective directions.

We can use this feature of anisotropic materials to design new THz polarization converters in order to achieve the mutual conversion between liner polarization and circular polarization of electromagnetic waves.

Based on the quasi-optical methods, the T/R polarization isolation system consists of polarization and polarization converter is designed and implemented by the research about the structure of periodic metal and the relative electromagnetic properties of metamaterials. It has the characteristics of simple structure, mature manufacturing processes, low polarization isolation transmission loss, and low polarization conversion rounded axial ratio. It is one of the important trends in the future T/R polarization isolation duplexer.

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