Simulation Design of Reconfigurable Multifrequency Yagi Antenna

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Abstract. In order to reduce the operating cost and improve the benefits of communication system, it is a feasible scheme to reduce the number of antennas used while ensuring the communication quality. Because reconfigurable antenna has the characteristic of automatically changing a certain electrical characteristic parameter, it has become one of the hotspots in antenna research. In the design of this paper, reconfigurable antenna is realized by changing the working state of PIN diodes embedded in external feed matching network. The design of Yagi antenna is introduced below.

1. Introduction

Generally, the design methods of reconfigurable antenna can be divided into two categories: changing the structure of antenna unit and changing the external antenna feed matching network. The design methods of changing the structure of antenna unit can be further divided into the following three categories: controllable slot antenna, connection transition state and changing the antenna load. Because the design method of changing the antenna external feed matching network can not only simplify the design of multi-frequency reconfigurable antenna but also keep it in good working condition, it is one of the hot spots of modern reconfigurable antenna research.

1.1 Establishment of Analysis Model

In order to better illustrate the design principle of the antenna, a model of the antenna designed by changing the feeding network outside the antenna is established here, as shown in Figure 1.

![Figure 1. Design of reconfigurable antenna analysis model based on changing external feed matching network](image)

As shown in the figure above, the design idea of this method is to treat the antenna as a load. When the working state of PIN diode or switching device embedded in its matching network changes, the input impedance will change from left to right. That is to say, the reconfiguration of antenna frequency can be achieved by properly designing the external matching feeder network. The advantage of this design method is that the design of reconfigurable antenna can be divided into two parts: antenna design and
matching network design. In this way, different parts can be designed with different software, and the objects can be debugged separately. This greatly reduces the difficulty of designing reconfigurable antenna, especially for imitation. The real results are quite different from the actual test results, such as the Yagi antenna in the previous section.

1.2 Basic Theory and Selection of PIN Diode

In this design, PIN diode is the active device that changes the parameters of external feed matching network. Unlike ordinary diodes, its structure can be divided into three regions, i.e. P-type material region, N-type material region and intrinsic region, as shown in Figure 2.

![PIN Diode Structural Diagram](image)

**Figure 2.** PIN Diode Structural Diagram

The PIN diode presents different states under different dc bias. When the bias voltage is zero, due to the existence of depletion layer in the I region, it presents a high impedance state. In the case of positive bias voltage, PIN diode shows a state of low impedance, and its electronic value will further decrease with the increase of bias voltage. Its equivalent circuit and simplified equivalent circuit are shown in figure 3. When in reverse bias, PIN diode can be divided into three working states: when the reverse bias is small, it presents greater impedance than when in zero bias, and the impedance further increases with the increase of voltage; When the backbias voltage reaches a certain value, its region I is all depletion layer, which is equivalent to a constant capacitance. A further increase in the reverse bias leads to an avalanche effect, which presents a low impedance state. Figure 4 is the equivalent circuit and simplified equivalent circuit of the diode reverse bias.

![Equivalent Circuit of PIN Diode](image)

**Figure 3.** Equivalent circuit diagram of PIN diode at forward bias
For the encapsulated PIN diode, its equivalent circuit is shown in figure 5. Where, represents the shell capacitance, represents the parasitic capacitance and represents the lead inductance. Considering the numerical characteristics of the equivalent circuit of PIN diode in microwave frequency band, this circuit can be further simplified, and the simplified circuit is shown in figure 6.

The PIN diode can be reshaped for low frequency ac signals, but it can only be considered as a linear component for high frequency ac signals. When both the dc bias and microwave signals are loaded at both ends of PIN diode, the impedance of the microwave signals is only related to the dc bias and has nothing to do with the microwave signals since the microwave signals are generally small. Therefore, we can control the way of microwave signal transmission by loading different bias voltage in PIN diode.

2. Electromagnetic Simulation of Reconfigurable Antenna
The reconfigurable antenna designed in this paper is also a multi-frequency antenna. Therefore, in order to ensure the accuracy of simulation, three setups should be designed for three frequency bands.
Since this reconfigurable antenna is based on the yagi antenna, three reference points are set at 1.9GHz, 2.5 GHz and 3.5 GHz.

Because this paper simulates the working frequency of the reconfigurable antenna of PIN diode at different bias voltage, two simulation engineering documents are required for its design. The two engineering document Settings must be exactly the same, except for the model used to represent the different working states of the PIN diode. The design model of this multi-frequency reconfigurable yagi antenna is shown in figure 7. By changing the working bias state of PIN diode, that is, changing the PIN diode model in the simulation software, a reconfigurable yagi antenna based on single branch matching is designed by changing the external feed network of the antenna, and the simulation results are shown in figure 8.

![Figure 7. Schematic diagram of design model of multi-frequency reconfigurable yagi antenna](image)

![Figure 8. S (1,1) simulation results when PIN diode embedded in the matching network is at different bias](image)

According to figure 8, when the PIN diode embedded in the matching feed network is in forward bias, the resonant frequencies of the three bands of yagi antenna are 1.974GHz, 2.506GHz and 3.477GHz respectively. When the PIN diode embedded in the matching network is in reverse bias, the resonant frequencies of the three bands of yagi antenna are 1.860GHz, 2.508GHz and 3.488GHz respectively. That is, when the bias voltage changes, the resonant frequency of yagi antenna will automatically change, and the resonant frequency at the low frequency band changes greatly, while the resonant frequency at the high frequency band is basically unchanged. Through this design method, the frequency reconstruction of multi-frequency and multi-branch yagi antenna is realized.

3. Conclusion

In order to reduce the design difficulty, this paper adopts the method of changing the antenna external feed matching network. The biggest advantage of this method is to realize the design and debugging of antenna and external feed matching network respectively. According to the simulation, when the PIN diode embedded in the single-node matching circuit is at positive bias voltage, its resonance frequency is 1.974GHz, 2.506GHz and 2.477GHz. When the PIN diode embedded in the single-node matching
circuit is in reverse bias, the resonant frequencies are 1.860GHz, 2.508GHz and 2.488GHz. That is to say, when the PIN diode is embedded in the matching network and in different states, the resonant frequency at the low frequency band is offset greatly, while the resonant frequency at the high frequency band is almost unchanged, realizing the frequency reconstruction.

4. References
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