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Access Circuit Design for High Isolation and High Power Co-channel Communications

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Abstract. The system spectrum resources are utilized more efficiently by sending and receiving signals in the same frequency. Long-distance co-channel systems require high power and high isolation HF tuner transceiver access modules. This paper designs a wireless communication co-channel access solution. The design uses a high power PIN diode switch structure. The on-off ratio within the scope of work has been given. The circulator performances under different environments are compared. At the same time, communication experiments were performed by using the design in different channel environments. The results show that this design has good adaptability in different complex environments.

Keywords: High power, co-channel communication, transmitter-receiver isolation, PIN diode.

1. Introduction

A co-channel communication system refers to a communication system with transmitters and receivers operating in the same frequency. In this operation mode, the transmitter end and the receiver end can't separate useful signal and interference signal by using filters. Therefore, the system shall use a HF tuner transceiver access module to separate the send and receive signals so as to improve the performance of the receiver. Long distance communication system requires high transmission power, thus demands the access module with a high degree of isolation. The main transmitter-receiver isolation measures currently adopted by co-channel communication systems are circulators, RF transceiver chip and electromagnetic relays, etc.[1]

Reference[2] Designs a circulator for UFH-band with up to 30 db isolation in the passband. As influenced by frequency, the size of the circulator decreases as the frequency increases, so it is difficult to make the circulator smaller and lighter in short wave band. Moreover, when the current passing through the circulator is too high, ferrite materials may have effect of excitation loss. Third-order intermodulation distortion phenomenon may emerge at the same time which will cause serious nonlinear effect.

GaAs RF transceiver chips have higher isolation, but it is difficult to operate in high power state, so it is commonly used in low power wireless devices.

Reference[3][4] introduce several kinds of electromagnetic relays. Electromagnetic relays inevitably have serious electromagnetic interferences due to their inherent structures. Therefore, additional shielding measures should be taken. The switching speed is in the millisecond region, not suitable for the rapid switching communication system.

Based on the above analysis, this paper designed a high-power and high-isolation co-channel wireless communication access scheme. A high-power and high-isolation switch structure is used to replace circulator and electromagnetic relay. Tests are conducted to compare the performance of the circulators, communication tests are conducted in different complex environments.

2. Co-channel Access System Design

2.1. Wireless HF Co-channel Access Module Design

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HF scheme design is directly related to the whole system communication distance and communication performance indexes. In view of the system requirements in practical application, the scheme mainly includes RF transmit module, RF receive module and co-channel access module. Figure 1 shows the block diagram of the design.

Analog RF part uses a dedicated communication frequencies to the shortwave. Since the frequency deviation has a greater impact on the performance of the multi -carrier modulation system, When we design the tuner, we should give full consideration to the LO accuracy and Doppler shift effects on the frequency offset, and take the system requirements for linearity into account, because the phase noise of the local oscillator signal is directly related to the performance indicators. The local oscillator chip ROS-368 in the design, can achieve a phase noise down to -92dbc/Hz @ 1KHz. PLL chip ADF4002, has a simple microarray data structure and is easy to develop. Power amplifier module using Mitsubishi RAxxH3340 series , this module provides a simple design and implementation , and its similar PIN-TO-PIN -compatible power amplifier products , can provide different output power indicator , may facilitate the application of different application scenarios .

The RF transceiver section uses PIN diodes[4] to design time-division switching circuit. Its advantage lies in : a small package to reduce PCB area ; fast switching rate, whose minimum up to 2 microseconds , far less than the protection timeslot of co-channel division switches ; high operating power, whose maximum reverse voltage up to 50V; high isolation whose off resistance is 10K ohms ; low insertion loss , whose resistance is less than 1 ohm; can be cascaded, for each additional one , isolation increases 6db; guide through current is small, you can use ordinary NAND gate devices drive it directly .

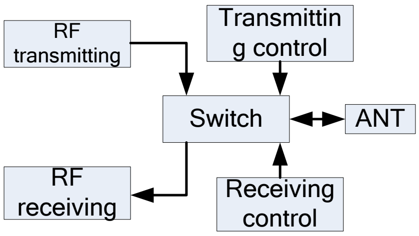

Fig. 1 high frequency wireless access module design block diagram

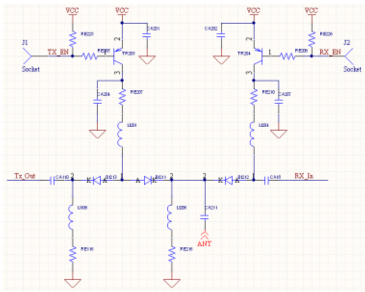

Fig. 2 PIN diode switch structure

As shown in figure 2, in order to provide higher transceiver isolation, and reduce the insertion loss and the static noise at the receiver, cascades two PIN diode switch in receiver. For the convenience of measurement, the large signal transmitting power was set to 34.5dbm which closed to maximum linear output power of the power amplifier module. The Tx_out power of small signal was set to 0 dbm. Figure 3 is the on-off ratio characteristics in each working state of the switch.

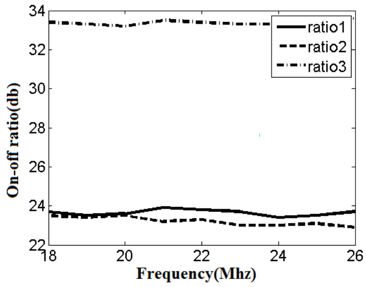

Fig. 3 different power and the working status of on-off ratio

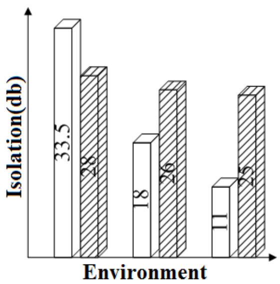

Fig. 4 isolation ratio under different environment

In figure 3, ratio1 indicates the on-off ratio in the small signal transmitting state. Ratio2 indicates the on-off ratio in large signal transmitting state. Ratio3 indicates the on-off ratio in the receiving status. Figure 3 shows that the switch scheme has an excellent consistency within the transmission band which the in-band flatness is less than 0.6 db. And has the stable high isolation ratio which the minimum on-off ratio is greater than 23 db. The co-channel interference can be controlled in a very low level if using a rf transceiver chip at the receiver after this switch structure.

At the same time in order to verify the adaptability in different environments, the contrast test has been done respectively for circulator and rf PIN diode switch. As shown in figure 4,the results of the isolation performance was given. From left to right in figure 4, indicates respectively the isolation performance on the indoor environment, the outdoor near-field reflective environment and the open outdoor environment. The blank column represents the isolation ratio of circulator in different environment. Twill column represents the isolation ratio of the PIN diode switch in different environment. Test results show that the PIN switch have higher isolation and greater consistency compared with the circulator on different environment.

2.2. BASEBAN PLATFORM CHOICE

Orthogonal frequency division multiplexing (OFDM) is a multi-carrier modulation technique being widely used in the field of wireless communication[6]. The test uses this technology as baseband platform. The chip of SPC200e designed by The original French SPiDCOM company is used for power line communication (PLC) system[7]. Spectrum management is implemented using a 1024-OFDM and the raw data rate reached up to 224 Mbps. Its main features include: there are 7 independent sub-bands from 2 to 30MHz, each sub-bands has independent pilot signal, according to the results of the channel estimation from each sub-bands, the chip can be modulated from BPSK to 256-QAM. Each sub-bands can be individually opened or closed with the unique broadband spectrum management mode. Also it can be applied to different bandwidth system. Based on these characteristics, especially in spectrum management, this baseband platform has a great advantage for wireless communication.

2.3. NETWORKING MODE SELECTION

The baseband test platform can support two networking mode. One is the master - slave mode. Another is Ad hoc mode. The first mode belongs to the star-network structure with only one center node. Other slave nodes can communicate with the center node, and also can communicate between two slave nodes with each other by the center node’s retransmission. The second mode is a kind of self-organizing network without center, namely there is no fixed center node. Each node of the network is peer-to-peer connective. Joining or exiting for each node will not affect the work of the whole network, and the nodes can automatically complete the networking when the neighboring node is detected.

In this platform, the default state is MS mode. Users also can choice ad-hoc network mode according to the different conditions for completing networking quickly.

3. Communication test in different environment

3.1. DATA TRANSMISSION TEST IN THE LABORATORY CONDITION

As a reference, the performance test was done in the laboratory condition to verify the applicability of the communication system. Using the attenuator, connect to wireless channel test block diagram as shown in figure 5:

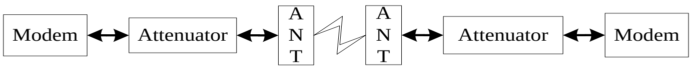

Fig. 5 terminal equipment laboratory test block diagram of the Internet

In the above figure, the distance between two antennas is 20m, more than ten times longer than the wavelength of the work frequency, so there is no near field effect. Attenuators are of 30db. In the corridor (tunnel environment) and roof (free space environment), almost identical test results are obtained. In the corridor environment, for example, the communication bandwidth is set to 8MHz, the following results are observed via the monitoring software.

Blue lines in this graph Fig. 6 represent the frequency spectrum of the received signal. Green lines represent the quantization noise of the receive channel. Orange blocks represent the received modulation mode. Gray blocks represent the local transmit modulation mode. As is shown in this figure, modulation demodulation of all sub-carriers at the transmit end and the receive end can achieve 16QAM. The blank area between the two color blocks represents the protected bandwidth. In such channel condition, the communication rate measured by the monitor software can be up to 13Mbps.

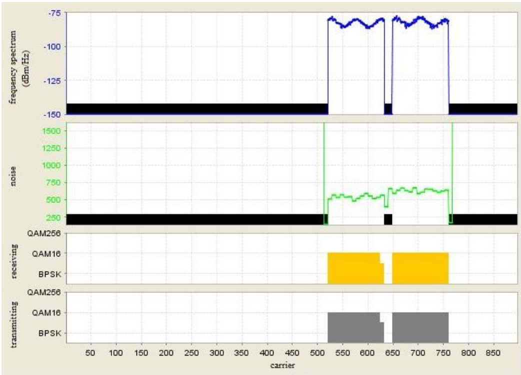

Fig.6 Communication Modem Mode in Corridor Environment

3.2. Channel Model Analysis

In the free space environment, the power attenuation of the wireless signal is given by the following equation (1):

$$\mathrm{Los} = 32.44 + 20\mathrm{lgd}\left(\mathrm{km}\right) + 20\mathrm{lgf}\ \left(\mathrm{MHz}\right) \tag{1}$$

In equation (1) calculation, when the distance is 20m, the system signal attenuation from the transmit end to the receive end is about 49db. The co-channel attenuators at the transmit end and the receive end are 60db. Therefore, when the total attenuation of the co-channel communication system in the corridor environment or the free space environment is 109db, it can provide high data rate communication. If we input the value in the above equation, the system theoretical communication distance is about 20km in the free space environment.

Under this test condition, the channel can be equivalent to a Rician channel. But in actual communications, there is no ideal direct path channel in most cases. Therefore, in practical channels, such as in urban environment, there are building blocking and reflection, tree-line blocking, etc[8]. In a mountainous environment, the communication system will face problems such as mountain reflection, tree blocking, and even mountain blocking. In such cases, the communication mode can only rely on short wave diffraction and reflection[9]. Communication performance will be seriously degraded. A channel model widely used in nowadays is the HATA model which has corresponding correction factors for different application environments. In an urban type channel, the attenuation model can be listed as the following equation (2):

$$Los = 69.55 + 26.16\lg f_c(\mathrm{MHz}) - 13.82\lg\mathrm{h}_t - \alpha(\mathrm{h}_r) + (44.9 - 6.55\lg\mathrm{h}_t)\lg d(\mathrm{Km}) \tag{2}$$

Where, $a(h_r) = \left(1.1\lg f_C - 0.7\right)h_r - \left(1.56\lg f_C - 0.8\right)$, h_t is the height of the transmit antenna. h_r is the height of the receive antenna. In this channel attenuation model, if the communication rate is maintained at 13Mbps, the effective communication distance should be 0.6km. So, when the system communication range is up to 5km, the modulation mode and data rate will be reduced accordingly.

3.3. Communication Tests in Complicated Environments

In the actual urban environment test, mobile communication capability is tested. The test layout is: a device is mounted on the roof of a high building; a mobile device is mounted on a vehicle; the communication bandwidth is fixed at 8MHz. The longest test distance is 4.7Km. At this distance, the communication data rate is up to 1Mbps, ensuring good two-way audio and video transmission.

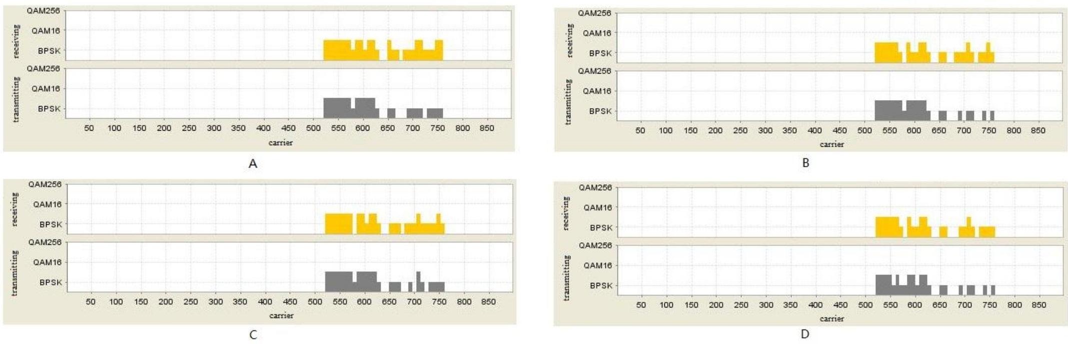

Fig.7 Communication Modem Mode in Urban Environment

In figure 7, A, B, C, D represent the different modulation and demodulation modes adopted by the transmit module and receive module at different straight line distances between the mobile station and the base station in the urban environment. The distances are respectively 1.8km, 3.0km, 3.7km and 4.7km.

In the mountainous environment test, two given mobile devices are used. For safety reasons, the maximum relative speed is maintained at 100 km/s, the communications bandwidth is set to 4MHz. The communication test is conducted in the actual mountainous area. At the farthest distance of 3.6 Km, communication rate is up to 760 Kbps, allowing two-way audio and video transmission in one channel.

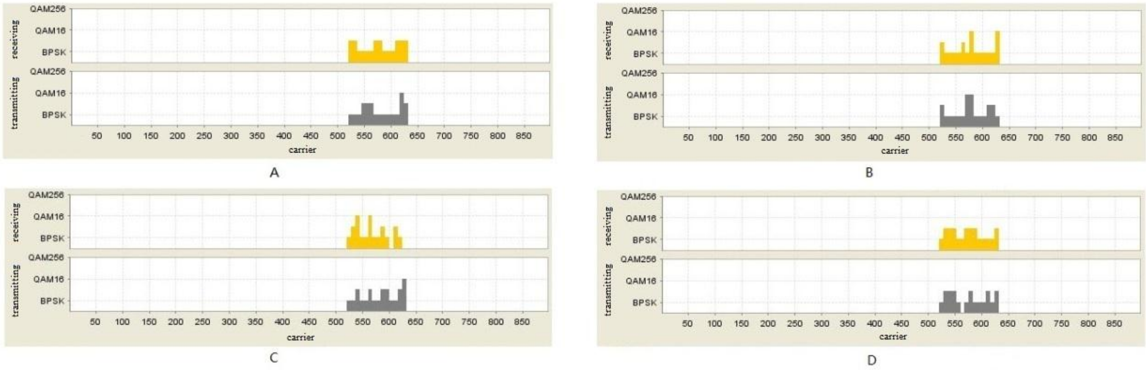

Fig.8 Communication Modem Mode in Mountainous Environment

In figure 8, A, B, C, D represent the different modulation and demodulation modes at different straight line distances between the two mobile stations in the mountainous environment. The distances are respectively 600m, 2.7km, 3.6km and 5.8km. Test results show that the system can effectively work in the mountainous area.

4. Conclusions

In this paper, we design a high isolation and high power co-channel access circuit scheme. The design uses a high power PIN diode switch structure that significantly reduces the co-channel interference and static noise at the receive end of the co-channel communication system. The on-off ratio within the scope of work has been given. The circulator performances under different environments are compared. Test results show that this design has better consistency. The antenna is driven directly by the power amplifier module via diodes, so the system can transmit energy signals to the maximum limit, eliminating some intermediate parts, allowing circuit board to be smaller. OFDM is used as the baseband platform. Communication tests are run for this design under different channel environments. Test results show that the proposed scheme can be applied to co-channel wireless communication system in complex environment.

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