Millimeter wave Broadband Co-frequency Duplex Yagi Antenna Based on Self-packaged Multi-layer SISL

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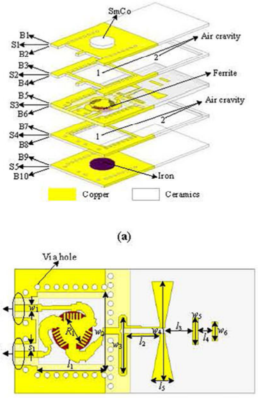
Abstract

In this paper, a broadband co-frequency duplex Yagi antenna for 5G millimeter wave band is proposed based on the LTCC multi-layer SISL. The antenna structure is self-packaged and has excellent performance. The center frequency of the co-frequency duplex Yagi antenna is designed at 33.25GHz, and the 10dB impedance relative bandwidth is 25.6%. The transceiver port isolation of the antenna is 12.7dB, and the maximum gain is 6.3dB. The cross-polarization levels of the main radiation directions of the E and H planes of the antenna are below -15dB.

CO-FREQUENCY DUPLEX ANTENNA CONSTRUCTION

The three-dimensional structure of the proposed co-frequency duplex Yagi antenna is shown in Fig.1. The co-frequency duplex Yagi antenna is composed of five layers of dielectric boards and ten layers of metal, the main circuit of the antenna is located on the B5 surface of the core layer S3 layer. The dielectric boards S1, S2, S4 and S5 are all ceramic with a permittivity of 6 and a loss tangent of 0.002. The thickness of the dielectric boards S1, S2, S4 and S5 is 0.192mm, and the thickness of the core layer S3 is 0.288mm. The five-layer dielectric board is packaged by the LTCC process. The proposed antenna is composed of a circulator module and a planar Yagi antenna, which are placed in the air cavity 1 and the air cavity 2 respectively. The side walls around the upper and lower air cavity 1 of the circulator module are fully metallized and packaged, which reduces radiation loss and improves antenna gain. The antenna module consists of a director, a reflector and a radiator. The air cavity 2 in the dielectric boards S2 and S4 is covered with copper on the inner sidewall of the circulator module, and together with the metallized through holes on the nearby dielectric board S3 and the metal ground form the reflector of the antenna. The director is composed of two rectangular vibrators, and the radiator uses a butterfly vibrator instead of a rectangular vibrator to expand the antenna bandwidth and improve the isolation of the transceiver port. Ferrite is embedded in the core layer S3, its saturation magnetization is 5200 gauss, the dielectric constant is 13.5, the diameter is 1.5mm, and the thickness is the same as that of the dielectric board S3. A permanent magnet (samarium cobalt) is embedded in the dielectric board S1 to provide a bias magnetic field for the circulator module. A circular iron block is placed in the air cavity 1 of the dielectric board S4 to enhance the magnetic field.



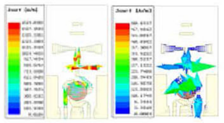
(a)

(b)

Fig.1. (a) 3D structure of co-frequency duplex Yagi antenna (b) Schematic diagram of the antenna core layer circuit

PERFORMANCE ANALYSIS OF ANTENNAS

The surface current distribution of the antenna is shown in Fig.3. It can be seen that when the antenna is in the transmitting mode, the current mainly flows from the transmitting port of the circulator module, passes through the antenna module, and is finally converted into electromagnetic waves and radiated in free space. During this process, the current hardly flows into the receiving port. Similar to the transmitting mode, when the antenna is in the receiving mode, the electromagnetic wave is converted into electric current through the antenna module, and flows through the receiving port of the circulator module. During this process, almost no current flows into the transmitting port. It can be concluded that the transceiver port of this antenna has good isolation.



(a) (b)

Fig.3. Surface current distribution of the antenna at 34GHz. (a) transmit mode surface current distribution. (b) receive mode surface current distribution.

The core of the circulator module is a ferrite material. The selection of ferrite parameters is very important. The radius of the ferrite can be obtained by (1), where μ_e is the effective magnetic permeability.

$$R=\frac{1.84\times c}{2\pi f_0\sqrt{\varepsilon_r u_e}}$$

The effect of ferrite materials with different diameters on the antenna is shown in Fig.4. It can be concluded that the diameter of the ferrite mainly affects the working frequency of the antenna. With the increase of the diameter of the ferrite, the working frequency of the antenna shifts downward, the overall reflection coefficient decreases and the bandwidth becomes wider. Considering the factors of volume and electrical properties, the final selection of the ferrite diameter is: fer_R=1.5mm.

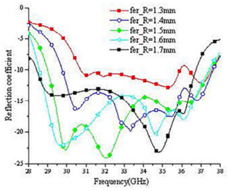


Fig.4. The effect of ferrite materials of different diameters on the proposed antenna.

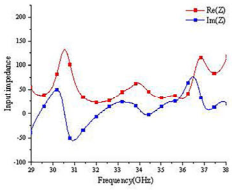


Fig.5. The input impedance of the proposed antenna.

Fig.5. shows the result of the input impedance of the antenna. It can be seen that the real part of the antenna impedance changes flat in the passband range, the overall trend tends to 50Ω, and the imaginary part of the antenna impedance tends to 0Ω as a whole, showing a good Broadband characteristics, the antenna obtains good impedance matching.

RESULTS

The co-frequency duplex antenna is simulated using HFSS. Fig.6. shows the final simulated gain, reflection coefficient and isolation graph of the antenna. It can be seen that the -10db impedance bandwidth of the antenna covers 29GHz-37.5GHz, and its relative bandwidth is 25.6%. The antenna reaches the maximum gain at 35GHz, the maximum gain is 6.3dBi, the overall gain of the antenna is above 4.8dBi, and the isolation of the transceiver port is below 12.7dB. The efficiency result of the antenna is shown in Fig.7. It can be seen that the efficiency of the antenna in the entire passband is above 70%, and the efficiency of the antenna in the entire passband is above 70%. The normalized radiation patterns of the antenna at 30GHz, 34GHz, and 37GHz are shown in Figures 8, 9, and 10. It can be seen that the pattern of the antenna in the entire passband remains stable with little change, and has an excellent cross-polarization level. The cross-polarization levels in the main radiation directions of the E-plane and H-plane are both below -15dB.

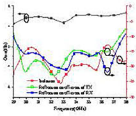


Fig.6

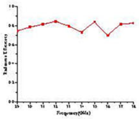
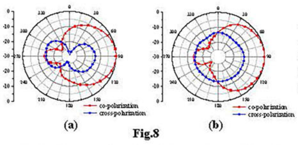


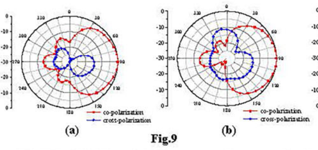
Fig.7

Fig.6. Gain, reflection coefficient and isolation results graph of the proposed antenna. Fig.7. Efficiency results of the proposed antennas.



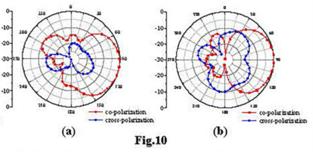
(a) (b)

Fig.8



(a) (b)

Fig.9



(a) (b)

Fig.10

Fig.8. The normalized radiation pattern of the antenna at 30GHz. (a) E-Plane. (b)H-Plane.Fig.9. The normalized radiation pattern of the antenna at 34GHz. (a) E-Plane. (b) H-Plane.Fig.10. The normalized radiation pattern of the antenna at 37GHz. (a) E-Plane. (b) H-Plane.