RESEARCH ON METAMATERIALS ABSORBER

Shicheng Fan, Yaoliang Song

School of Electronic and Optical Engineering
Nanjing University of Science and Technology,
Nanjing, 210094, China
313104002292@njust.edu.cn, ylsong@njust.edu.cn

Artificial stealth materials have widely applications in areas such as radar target stealth, antenna design and electromagnetic protection etc. However, absorber based on traditional structures for the radar targets stealth application is facing big challenges on absorbing frequency, bandwidth, bulky and poor flexibility and other practical problems. Fractal structures different from the traditional structures, it has self-similarity, can have a fine structures in any small scale , if it can be used in the designing of microwave absorber combined with characteristics of surface fulling curves and will break through existing barriers. Our research aims at these tough problems of designing the artificial broadband radar stealth materials, a new broadband composite structure based on fractal curves and flexible magnetic material are proposed, in which new ideas combine new structure and material. The goal of the project is to research on design methods, theoretical modeling, absorbing mechanism of new broadband absorbing materials, through experiments to verify the feasibility of experiment design method. It will lay a solid theoretical foundation for solving the problems on working frequency, bandwidth, and flexible aspects of design methods of existing absorber. According to this situation, our work mainly focuses on three aspects broadband, miniaturization, and conformal. Based on three aspects we have done the following work.

We have present a broadband polarization insensitive prefect metamaterial absorber based on fractal structures.

Through the combination of fractal and circular structure, the bandwidth is extended without increasing the size of the unit cell. A simple parallel equivalent circuit model has been proposed describing the absorption phenomenon to predict the frequency of absorption of the proposed absorber. The simulated result shows that the absorber’s full width half maximum is 18.5 %. With rotational symmetry structures, the absorber is insensitive to the polarization. The incident angles at which the metamaterial absorber can maintain 50 % of the absorbance are up to 50. With the geometrical scalability, the absorber can be extended to any frequencies. This absorber is fabricated and measured at X-band, and the experimental results coincide well with the simulation results.

Multiband absorbers based on ultra-thin multi-layer structures, with different bandwidth characteristics, are presented. The proposed structure is composed of three vertically stacked metal- dielectric layers backed by a metal ground. All the metallic patches are symmetrical T-shape and have different geometrical dimensions, which can be manipulated to design six-band. A simple series equivalent circuit model has been proposed describing the absorption phenomenon to predict the frequency of absorption of the proposed absorber. The designed structures are polarisation-insensitive as well as wide-angle absorptive for both TE and TM polarisations. The 3 dB broadband structure, exhibiting an absorption bandwidth of 40 % at 10 GHz, has been fabricated and the absorption performance has been verified with the simulated response. The proposed absorber has the advantages of ultra-thin thickness, compact size, simpler design, tunable absorption bandwidth and experimental validation, which makes it a promising candidate for many potential applications.

Based on the analysis of the circuit model, we conclude that increasing the resistance of structure can greatly expand the bandwidth. We have present an ultra-wideband flexible absorber by loading chip resistors. Simulated results show that the bandwidth of the proposed absorber with absorptivity more than 90 % is 2.56-10.03 GHz with a relative bandwidth over 118.5 %. Bandwidth is much wider than the existing design. Moreover, the absorption peak remain high with large angles of incidence for both TE and TM polarizations. This absorber has been fabricated and measured, whose measured results coincide well with the simulation results. The fabricated absorber has the advantages of convenient to be carried and flexibility that can easily be conformed to cylindrical and spherical. The proposed absorber also possesses many advantages such as polarization-insensitive, wide-angle, low profile and lightweight that make it easier to apply.

We have present an UHF prefect metamaterial absorber by combining coupling lines and fractal lines with very small unit cell. The proposed absorber consists of surface metal structure and metallic background plane, separated by a dielectric substrate and air. Simulation results show that the absorber has absorption peak at 442MHz with 99.73% absorptivity. The ratio between lattice constant and resonance wavelength is 1/68, significantly less than the existing absorber. According to the absorption mechanism of proposed absorber the design principle is introducing in detail. Moreover, the absorption peaks remain high with large angles of incidence for both TE and TM polarizations. With the geometrical scalability, the absorption peaks can be changed to any frequencies, such as 433 MHz and 5 GHz. The proposed absorber also possesses many advantages such as polarization-insensitive, wide-angle, low profile and lightweight that make it easier to apply. Due to the small ratio, it can be widely used in radiation suppression for microwave relay communication such as mobile communication and wireless network by changing the parameters of structure.

Absorbers can be used in many applications, but they need to be conformal, low profile, and lightweight. Flexible devices have many advantages over their non-flexible counterparts such as much lighter in weight, much smaller in size, much more durable, and outstanding flexible and conformal ability. Flexible MM absorbers which typically fabricated using flexible dielectric layer such as MM film, polyimide layer, and polydimethylsiloxane (PDMS) layer can be easily conformed to the unusual surfaces such as cylindrical, pyramid, and spherical. We have utilized polyimide material and air layer in our design, foam and glue can be used instead of the original thick dielectric layer. All absorbers we proposed possesses many advantages such as low profile, conformal and lightweight that make it easier to apply. At the same time, we conducted experimental measurements on various complex application scenes, for example, the cylindrical RCS reduction effected measurement and RCS reduction of missile model. The actual verified the flexible absorbing body good applicability.

The main research content we have already done is for radar stealth, so the design of the band is in the L (1GHz-2GHz), S (2GHz-4GHz), C (4GHz-8GHz) and X (8GHz-12GHz) band, with the application of the THz is more and more widely, we need to re-examine the design method. Firstly, Circuit's equivalent model needs to be re-researched. Secondly, in THz, many fine structures cannot be realized due to the limitation of processing accuracy, such as multi-level fractal. Third, the size of the absorber corresponding to THz is very small, so the chip resistance cannot be loaded. This is a big difficulty for the design of THz broadband absorbers. According to this situation, our work mainly focuses on three aspects equivalent circuit model proposed, design of surface structure, and research on dielectric layer. Based on three aspects we need to do the following three aspects.

1 Analysis of equivalent circuit models of absorber in THz frequency band. To research the effect of surface structure, dielectric layers dielectric loss and magnetic loss on absorptivity. Research on the equivalent circuit model of double-sided absorber.

2 Research on structural design based on fractal, mainly utilize multi-layer structure to extend the complexity of fractal. Research on how to increase the resistance of the surface structure to increase the absorption bandwidth.

3 Design of metallopolymer polydisperse. It is also necessary to measure the electromagnetic parameters of the metallopolymer polydisperse. Research on periodic cell structures of the novel absorbers from the conventional double PCB to metallopolymer polydisperse and flexible metamaterials.