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MICROSTRIP PATCH ANTENNA LOADED WITH FERRITE FILMS FOR UMTS APPLICATIONS

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ABSTRACT

This paper presents the novel design of a microstrip antenna loaded with ferrite films as a substrate material. The antenna is designed to operate in the frequency range of up to 2.1 GHz which is suitable for UMTS applications. The antenna is composed of a rectangular-shaped patch antenna with thin ferrite films as a substrate. Miniaturization is achieved by using ferrite films with a high dielectric constant to increase antenna gain and decrease antenna size. High-Frequency Structural Simulator (HFSS) is used to simulate the antenna design and the results are compared with the measured values.

Keywords: Patch antenna, ferrite films, UMTS, operating frequency, gain.

INTRODUCTION

An antenna printed directly onto a circuit board is termed a microstrip antenna. It consists of a ground plane on one side of a dielectric substrate and a radiating patch on the other. Low gain and narrow bandwidth are the two main drawbacks while designing a microstrip antenna with a high dielectric constant. Wireless technologies advancement in the telecommunications industry requires patch antenna downsizing. In this design microstrip transmission line is used as a feeding technique. This is a type of electrical transmission line printed directly onto the substrate to supply power to the antenna. Microstrip antennas are used in a variety of applications, including wireless communication, satellite communication, and radar systems. Microstrip antennas are antennas printed on a substrate material, such as a printed circuit board (PCB). The substrate material, such as FR4, Rogers, or PFTE. Performance characteristics of the antenna, including bandwidth, gain, and radiation pattern, are influenced by the substrate material (F. Z. Hanin and L. Setti 2014). The substrate material also affects antenna size, shape, and cost. The ferrite film is a thin layer of ferrite material used as a substrate in various electronic applications. A magnetic material, iron oxide, is typically used in the production of ferrite films. They are used as a substrate for thin-film transistors, integrated circuits, and other electronic components. This paper will introduce thin ferrite films as a substrate to resonate the antenna in the frequency range of 1.9-2.1GHz which is suitable for UMTS applications. Ferrite-loaded patch antennas are crucial in UMTS (Universal Mobile Telecommunications System) applications, due to their ability to tune the operating frequency of the antenna. Third-generation mobile communication technology (UMTS) is used to give mobile users high-speed voice, data, and multimedia services. The high-frequency bands used in UMTS are typically very crowded, which can cause interference and reduce the quality of the signal. By using a ferrite-loaded patch antenna, it is possible to tune the antenna's operating frequency and avoid interference from nearby signals (F. Z. Hanin and L. Setti 2013).

In addition to their ability to tune the operating frequency, ferrite-loaded patch antennas can also provide excellent performance in terms of radiation efficiency, bandwidth, and directivity. The high magnetic permeability of the ferrite material can be used to improve the radiation efficiency of the antenna, which can result in a stronger and more reliable signal. This is especially important for UMTS applications, which require high-quality, reliable communication. Increasing the gain of an antenna can improve its ability to transmit and receive signals, and can make it more suitable for long-range communication. A substrate with a larger dielectric constant can enhance the gain of the antenna by reducing the surface wave losses and improving the efficiency of radiation. The amount of power that an antenna reflects on the source is known as return loss, and it can result in signal loss and lower antenna efficiency. An antenna's efficiency can be increased by using a matching network to match the feedline's and antenna's impedances, which lowers return loss. A microstrip patch antenna with a dielectric substrate will be compared to a microstrip patch antenna loaded with thin layers of demagnetized ferrite (G. M. Yang et al 2010).

METHODOLOGY

A. Working principle

The Faraday effect, which describes how electromagnetic waves' polarization rotates as they pass through a magnetic material, underlies the operation of microstrip patch antennas filled with ferrite films. When a magnetic field is supplied perpendicular to the wave's path of propagation, the wave's polarization rotates as a result of the Faraday effect. Being a magnetic material, the ferrite film on the antenna patch creates a magnetic field near the patch. This magnetic field interacts with the electromagnetic wave radiated by the patch, causing a rotation of the wave's polarization. The effective refractive index of the substrate material changes as a result of the polarization rotation, changing the wave's phase velocity. The resonance frequency of the antenna is impacted by a change in the wave's phase velocity. A microstrip patch antenna's resonance frequency is influenced by the physical parameters of the patch and the substrate material's effective dielectric constant. The ferrite coating modifies the substrate's effective dielectric constant, which changes the resonance frequency of the antenna. It is possible to produce a variety of antenna features, including beam steering, frequency tunability, and reconfigurability, by taking advantage of the shift in the antenna's resonance frequency driven by the presence of a ferrite film. The ferrite film can be controlled using an external magnetic field, which allows for remote control of the antenna properties.

B. Designation of a patch antenna

Designing a microstrip patch antenna loaded with ferrite films for UMTS applications requires a systematic approach that considers several design factors. The operating frequency for UMTS applications is in the range of 1920-2170MHz. This frequency range is commonly used for mobile communications. The substrate material for the microstrip patch antenna can be selected based on the dielectric constant, loss tangent, and thickness (G. M. Yang et al 2009). For a ferrite-loaded patch antenna, the substrate material should have a low dielectric constant and loss tangent. It is necessary to select the patch size, the feeding method, and the ground plane while designing a patch antenna. The patch dimensions are determined by the desired resonance frequency and the ferrite material used. The feeding technique can be a coaxial probe, microstrip line, or aperture coupling. The ground plane should be large enough to provide high radiation efficiency and reduce surface wave losses. The thickness of the ferrite substrate should be carefully selected based on the desired frequency range and performance requirements.

A patch antenna loaded with different substrate materials can offer several advantages over a traditional microstrip patch antenna. The electromagnetic characteristics of the antenna may be changed by altering the substrate material, which can have a major effect on the antenna's performance. The size of the patch can be decreased while still retaining an antenna-compatible resonant frequency by raising the substrate's dielectric constant. This can result in a smaller, more compact antenna that is suitable for use in portable devices (F. Z. Hanin and L. Setti 2016). Ferrite films can be used as a substrate material for patch antennas and can offer permeability that is much higher than that of typical dielectric materials, which can be used to tune the resonant frequency of the antenna.

The bandwidth, gain, efficiency, and polarization performance of a microstrip patch antenna is also impacted by the feeding method utilized. This method feeds the patch antenna using a microstrip line. This method enables simple RF component integration and offers good impedance matching.

The patch design calculations are shown below

1. Calculation of the width (w) based on (C. A. Balanis 2005) is:

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}}$$

2. The effective dielectric constant is derived as (ε_{eff}):

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}}$$

3. Effective length (L_{eff}) can be calculated as follows: $L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}}$

4. Length extension (ΔL):

$$L = L_{eff} - 2\Delta L$$

5. Calculation of the actual length (L):

$$\Delta L = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}$$

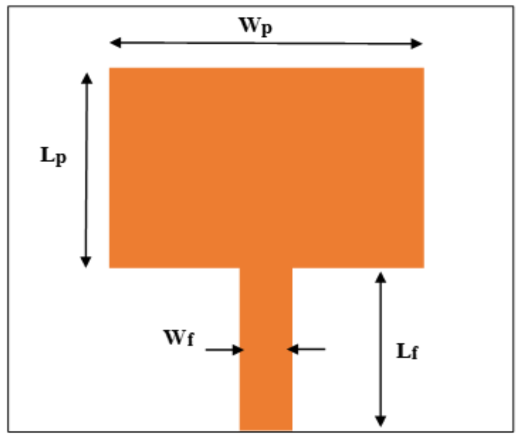

Fig. 1. Dimensions of the patch W_p=16.07mm, L_p=21.42mm, L_f=8mm, W_f=1.78mm

The patch is designed using FR4 Epoxy on a single substrate and then designed using a thin ferrite film between the patch and FR4 Epoxy. Finally, two thin ferrite films are placed between the patch and FR4 Epoxy and another film between FR4 Epoxy and the ground plane.

Case1: FR4 Epoxy between the patch and ground

Fig. 2(a): Single FR4 Epoxy substrate

Case2: Ferrite film between the patch and FR4 Epoxy

Fig. 2(b): With a single ferrite film

Case3: Ferrite film between the patch and FR4 Epoxy and between FR4 Epoxy and ground

Fig. 2(c): With two ferrite films

The above cases are designed and the results are observed. Using the HFSS software the resonating frequency is marked along with its gain(dB).

RESULTS AND DISCUSSION

The results show that the design using two ferrite films is more suitable for UMTS applications. The substrate material with a more dielectric constant can operate between 1920 and 2170 MHz which is suitable for UMTS applications. And the directional UMTS antenna with a gain of -7dBi is suitable for use in the 800/900/1710/1800/2100 MHz bands.

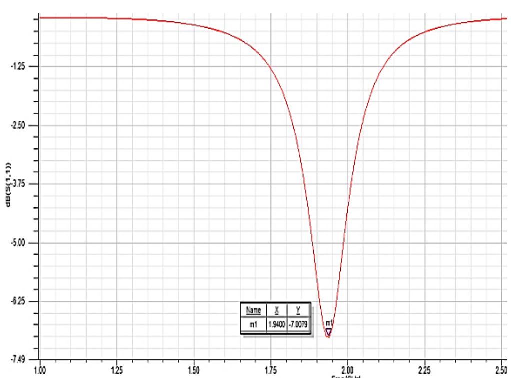

Fig. 3: Simulation results of a patch antenna with two ferrite films

The result (Fig. 3) shows the resonant frequency versus the dB graph. This graph shows the result from the case3 design model with two ferrite films of 2μm thickness. The antenna is resonating at 1.94GHz and has a gain of -7dB which is suitable for UMTS applications.

The high-frequency bands used in UMTS are typically very crowded, which can cause interference and reduce the quality of the signal. By using a ferrite-loaded patch antenna, it is possible to tune the antenna's operating frequency and avoid interference from nearby signals.

TABLE I. MEASUREMENT OF THE RESONATING FREQUENCY AND S11 PARAMETER FOR DIFFERENT SUBSTRATES AT 2.1GHZ OPERATING FREQUENCY

Observed the resonating frequency and gain(dB) values at 2.1GHz operating frequency for different substrates. As the dielectric constant of FR4 Epoxy (ε_r =4.4) is less so the gain is -23.05dB with 2.34GHz resonating frequency,

Operating frequency	Type of substrate	Resonating frequency	S11 (dB)
2.1GHz	FR4 Epoxy	2.34	- 23.054
2.1GHz	Single ferrite film between the patch and FR4 Epoxy	2.31	-7.050
2.1GHz	Two ferrite films between the patch and between FR4 and between FR4 and ground	1.94	-7.007

whereas with the introduction of single ferrite film and two ferrite films furtherly which has a more dielectric constant (ε_r =12) rapidly increases antenna gain to -7.05dB and this also helps for the decrease in size of patch antenna resulting in miniaturization. This type of patch antenna is more suitable for UMTS frequencies.

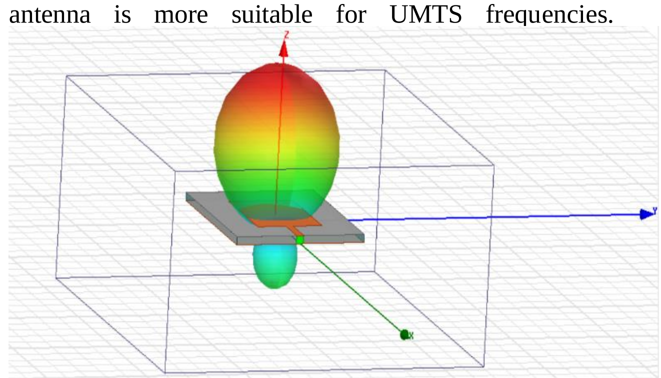

Fig. 4: 3D polar plot of a patch antenna with two ferrite films

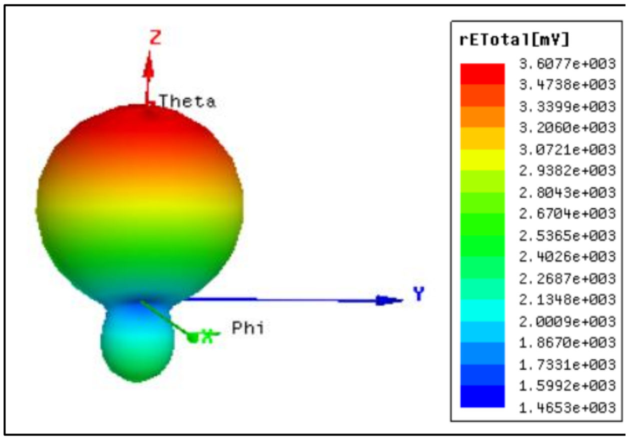

Fig. 5: 3D radiation pattern

CONCLUSION

By using ferrite films as a substrate material, which has a high dielectric constant, the antenna's gain is increased, making it resonate at 1.9-2.1GHz, an ideal frequency range for UMTS. Another advantage of using ferrite-loaded patch antennas in UMTS applications is their compact size and low profile. These characteristics make them suitable for use in compact, portable devices like smartphones and tablets, which are commonly used for UMTS communication. Overall, the use of ferrite films as a loading material for microstrip patch antennas is a well-studied approach that can be used to improve the performance of antennas for UMTS applications. It is feasible to lower the return loss and enhance the antenna's performance in terms of bandwidth and gain for a variety of applications by utilizing simulation tools to optimize the design.

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