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A Proposed model for frequency antennas used in mobile communication systems

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ABSTRACT

One of the most essential components of wireless communication systems, particularly in mobile devices, is the antenna. Covering a large range of operating frequencies while preserving excellent system performance over the whole operating frequency range is one of the desired characteristics of antennas. As a result, future antenna designs for mobile devices would greatly benefit from the ability to adjust the antenna's resonance frequency without changing its physical size. This study suggests a model for adjusting the ferrite material's electromagnetic characteristics to tune the inverted F-antenna's operating frequency across a comparatively large frequency range. It will be shown in this suggested model that the electrical regulation of the antenna's ferrite material's permeability successfully results in a notable change in its resonance frequency and, therefore, an increase in the communication system's overall performance.

1. INTRODUCTION

Recent advancements in modern communications technology have resulted in a greater need for reliable and efficient components used in the deployment of wireless communication systems. Since the antenna is one of the most crucial components of mobile devices, creating a reliable, efficient antenna that meets modern design

requirements is one of the main objectives for raising the general caliber of mobile communication systems. The extensive usage of mobile communication devices, especially smartphones, is one of the primary drivers behind the extensive research on internal antenna designs that may be included into these devices.

Consequently, a number of techniques and technologies were created to solve various antenna design issues. One of the main and most important design characteristics of the antenna is its ability to cover a wide range of operating frequencies without altering its shape or physical dimensions. The techniques developed to achieve this goal can be categorized into three main groups: (1) mechanical techniques, (2) electrical tuning ircuits, and (3) altering the electromagnetic properties of the antenna material, such as its conductivity, permittivity, and permeability [1, 2]. Mechanical methods include altering the shape or physical measurements of the antenna. Unacceptably lengthy wait times, unreliability, and a short system lifetime due to the mechanical components of the system are the disadvantages of these approaches. Alternatively, by modifying the electromagnetic properties of the antenna material, the resonance frequency of the antenna may be changed without the need for for changing its physical size or form [3-6]. The primary goal of this research project is to regulate the permeability of the antenna ferrite material, which causes the antenna's resonant frequency to vary significantly across a sizable frequency range. The literature has addressed the fundamental idea of electromagnetic frequency tuning. For instance, [7] describes how to electronically tune the frequency of the planar inverted F-antenna (PIFA) without the need for external wiring by utilizing an electronic tuning circuit made up of a radio frequency switch and other discrete passive components that are fully integrated into the antenna. The dual band PIFA antenna can operate well in four frequency bands thanks to this technique. Additionally, [8] discusses many techniques for resonant frequency adjustment of inverted F-antennas (IFA), which involve short pins and capacitors in different locations. In [9–12], other techniques for adjusting PIFA's resonance frequency are presented. Rather than regulating the electromagnetic characteristics of the antenna's material, these techniques depend on

rearranging the actual antenna size. A method for creating a tiny dual-band IFA using a series resonator is shown in [13]. In order to offer tunable loading effects according to the necessary resonant frequency of the antenna, this resonator is placed at the right end of the IFA. Conversely, [14] proposes a tuning circuit made up of a planar inverted F-antenna (PIFA) with a microfluidic impedance integrated into it. When combined with a straightforward double-stub, this microfluidic impedance allows the impedance to be changed by altering the stub length by the injection of a liquid metal alloy into the impedance's microfluidic channels. In order to adjust the dual band planar inverted F-antenna design's working frequency, [15–17] recommend adding an L-shaped slot with varying size. In [18–27], many methods for improving the performance of planar inverted F-antennas are discussed. These methods include: (1) reconfiguring high frequency patch antennas using liquid metal as a switching mechanism; (2) integrating a reconfigurable RF impedance tuner with broadband antennas; (3) enhancing the performance of dual band PIFA with a stub; and (4) designing printed PIFA utilizing a PCMCIA card. This study aims to provide an effective methodology for adjusting the inverted F-antenna's resonant frequency by regulated modification of the ferrite material's electromagnetic characteristics while maintaining the antenna's physical dimensions and form. By applying a controlled static magnetic field through the antenna's ferrite material, the suggested model modifies the permeability of the material, which in turn causes a shift in the antenna's resonant frequency. The overall performance of the communications system is improved by the controlled shift of the antenna's resonance frequency, which offers a fair amount of flexibility in operating the antenna across a very broad range of frequencies.

2. THEORYANDDISCUSSION

Iron oxide (Fe3O4) and nickle oxide (Ni2O3) are two examples of the magnetic metallic oxide combinations used to make ferrite materials. Ferrites may be used in a variety of industrial applications because of their electromagnetic properties. Ferrites may be identified by their high relative permittivity of 10 or more, high resistivity, and high relative permeability at low operating frequencies. The inverted F-antenna model that is suggested in this work is entirely composed of nickle oxide (Ni2O3). Ferrites' electromagnetic activity has been extensively studied in a number of scientific publications, including [2, 3]. This section provides a quick review of the literature on the properties of ferrites. The ferrite materials' electromagnetic characteristics are primarily caused by the electrons' rotations around the axis of the static magnetic field, $H0$, which generates the magnetic dipole moment at the atomic level. Figure 1 shows how the electron spin generates the dipole

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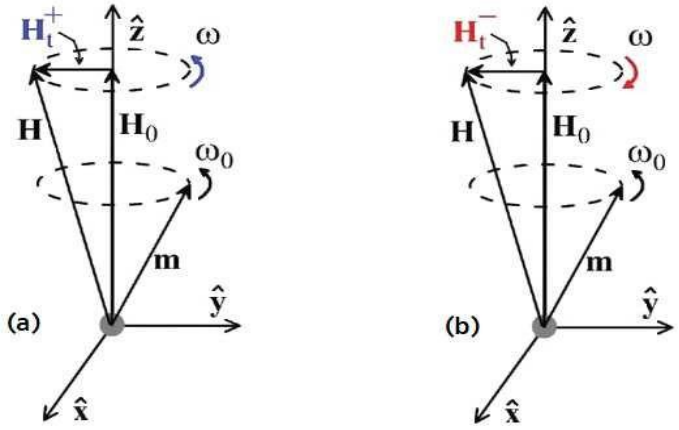


Figure1.Processofdipolemomentgeneration(m),underuniformstaticmagneticfieldH_0

In this case, the effective permeability μeff may be used to determine the range of change of the ferrite permeability that causes the resonant frequency shift. The magnetic field component of the electromagnetic radio frequency signal and the strength of the uniform static magnetic field $H0$ determine the size of μeff. A longitudinal bias with μeff=μ±δ, a transverse bias with μeff=(μ2-δ2)⁄μ, and a parallel bias with μeff=1 are therefore the three possible possibilities. It should be mentioned that electromagnetic waves may spread when there are longitudinal and parallel biases. Transverse bias, on the other hand, will cause μeff to be negative, which will prevent the waves from propagating. This happens when the RF electromagnetic wave's frequency falls between √f0(f0+fm)

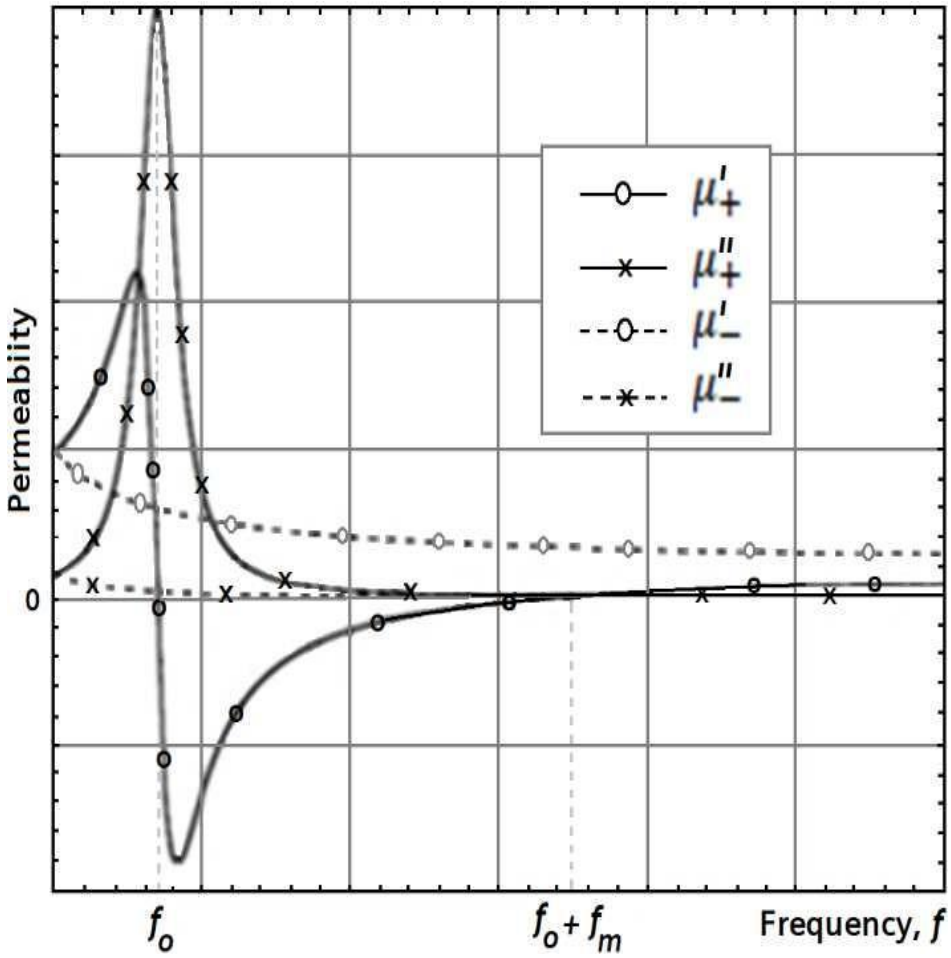
Magnetization saturation, or Ms, is the outcome of electron spins aligning to generate a relatively large unified dipole moment when a high intensity magnetic field is applied to ferrite material. The magnetization saturation Ms may be used to express the density of the magnetic flux needed to align the spins of every electron in the ferrite material. Furthermore, an additional relatively tiny RF alternating magnetic field with a radian frequency ω may produce a forced spin of magnetic moment. As a result, the Polder permeability tensor [4] is constructed in a way that:where $\boldsymbol{\zeta}$ is the permeability of the ferrite material and δ is an intermediate variable, as follows:

1 + ωm(ω0+jωL)(ω0+jωL)2−ω2 = μ = μ' − $j\mu$" Eqn = −ωmω0 (ω0+jωL)2−ω2 (2) (3) where ωL=πγΔH and ωm=8π2γMs. Lithium oxides, magnesium oxides, and nickle oxides are examples of ferrite materials that are commercially accessible in a variety of forms, such as sheets and bars. These ferrites typically have magnetic resonances between 10 Oersted≤ΔH≤900 Oersted and magnetization saturation values between 300

Gauss≤4πMs≤5000 Gauss. It is possible to express the radio frequencies as follows: fm=8γπMs, fL=πγΔH/2, and f0=γH0. All of these frequencies are quantified in MHz. The applied magnetic field B may be expressed in terms of the magnetic flux H as follows where the polarization of the magnetic flux H and the uniform static magnetic field B are both circular, with the clockwise and counterclockwise polarizations indicated by (+) and (-) signs, respectively:

where,μ_=(μ-δ),andμ+=(μ+δ).

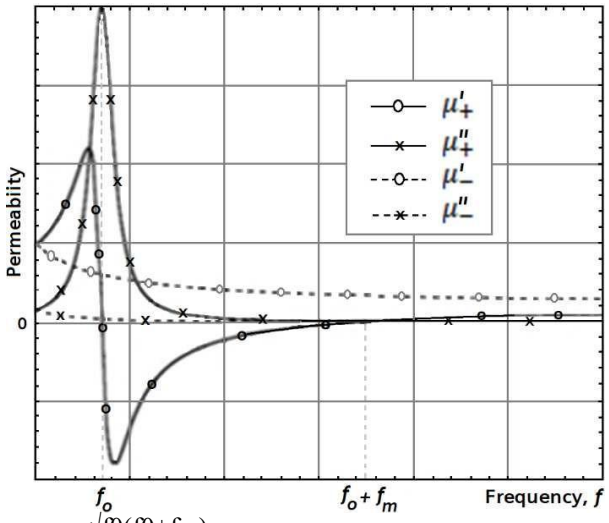
Figure 2 shows how $\mu-$ and $\mu+$ behave in



relation to the RF magnetic field's frequency. It is clear that μ" has a peak at $f0$, which represents the clockwise waves' resonance frequency. Furthermore, when the RF magnetic

field frequency falls between the range √f0(f0+fm)
Figure2.PermeabilityonnickleoxideversusfrequencyoftheRFmagneticfield
The following approximations can be considered in the magnetic saturation phase of the ferrite material: μ≅μ0 and μeff≅4πμ0γMr/f, where Mr indicates the residual magnetization in the ferrite material immediately upon turning off the uniform static dc magnetic field $H0$ [3, 4]. The antenna's frequency tuning range is determined by the relative change in the ferrite permeability δ, which is shown in Figure 3 in relation to the frequency of the RF magnetic field.where,μ_=(μ-δ),andμ+=(μ+δ).

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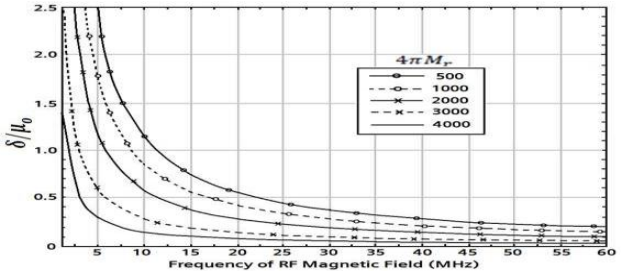


Figure3.Relativechangeinferritepermeabilityδ,versusfrequencyoftheRFmagneticfield [1]

Figure 3 shows that as the frequency of the RF magnetic field rises, the relative change in the ferrite permeability δ decreases exponentially. As a result, the antenna's maximum frequency tuning range also decreases. An electromagnet coupled to an adjustable dc voltage source may produce and regulate the static uniform magnetic field $H0$. Therefore, by altering the current in the electromagnet's coil, the static magnetic field $H0$ may be adjusted, therefore controlling the resonant frequency of a ferrite micro-strip batch antenna that is positioned within the electromagnet's core. For a rectangular ferrite micro-strip patch antenna, Figure 4 displays the inverted F-antenna's resonant frequency in relation to the uniform magnetic field $H0$ (Magnetic bias) [5]. This method offers a fair amount of control over the antenna's resonance frequency.

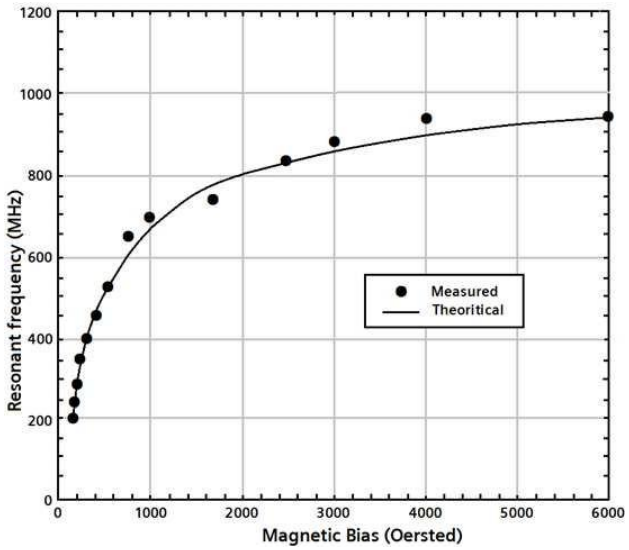
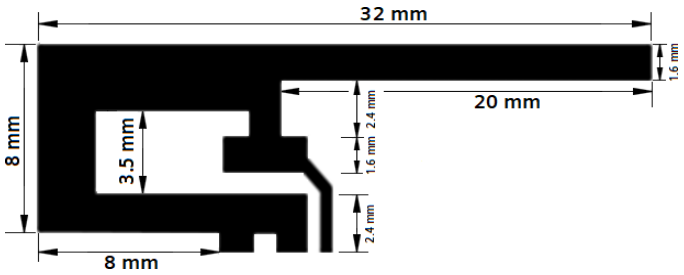


Figure4.ResonantfrequencyversusuniformstaticmagneticfieldH_0

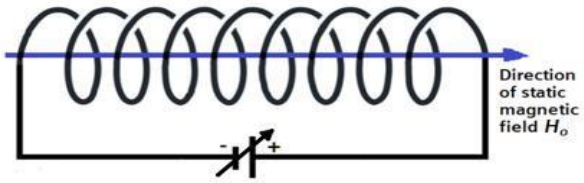
4. RESULTSANDDISCUSSIONS

This section presents a suggested model for an inverted F-antenna based on ferrite. A typical 2.4 GHz micro-strip Inverted F-antenna is shown in Figure 5(a). It is intended to be positioned within the coil shown in Figure 5(b) to offer complete exposure to the static magnetic field $H0$ generated by the coil. Conversely, Figure 6 shows a typical radiation pattern for the antenna, which consists of electromagnetic waves that are vertically polarized. It is important to note that simulation findings indicate that changing the resonance frequency has no discernible impact on the antenna's gain or emission pattern. However, the geometrical form and physical size of the antenna—which remain unaltered in the suggested model of the antenna—are the primary determinants of the radiation pattern and antenna gain. The antenna's feed-point reflection at two distinct resonance frequencies (2.4 GHz and 3.15 GHz) is shown in Figure 7. It is evident that for the 2.4 GHz and 3.15 GHz resonant frequencies, the feed-point reflections have the lowest values at around 2.41 GHz and 3.16 GHz, respectively, where the antenna has the lowest impedances and SWRs.

Figure 8 shows the antenna's resonant frequency versus the static uniform magnetic field $H0$ in two scenarios: (a) when the entire antenna is composed of ferrite material, and (b) when only the substrate is composed of ferrite material. These results are based on the theoretical analysis discussed in Section 2 and the results of MATLAB simulations. It is evident that case (a) performs better than case (b). Figure 8 shows that by changing the magnetic bias from 0.2 KOrested to 6.0 KOersted, which corresponds to a 31% frequency shift, the resonance frequency of the IFA may fall between 2.41 GHz and 3.15 GHz when the whole antenna is composed of nickel oxide. However, by changing the magnetic bias from 0.2 KOrested to 6.0 KOersted, which is equivalent to a 28% frequency shift, the resonance frequency of the IFA may fall between 2.41 GHz and 3.09 GHz when the substrate is solely composed of nickel oxide. In comparison to the situation when just the substrate is composed of ferrite material, it can be inferred that an antenna with a complete ferrite construction offers a greater range of operating frequencies. Nonetheless, a respectable enhancement in the antenna's performance is discernible in both situations, leading to a general increase in the wireless systems' overall performance.



(a)



(b)

Figure5.(a)2.4GHzinvertedF-antennamodel,(b)sourceofstaticuniformmagneticfield

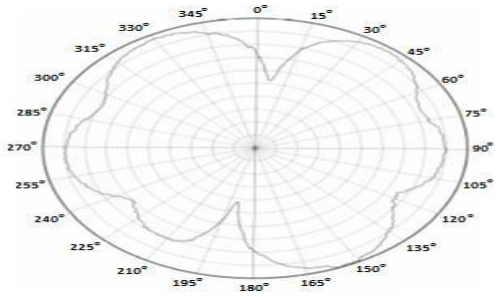


Figure6.Radiationpatternofatypical2.4GHzinvertedF-antenna

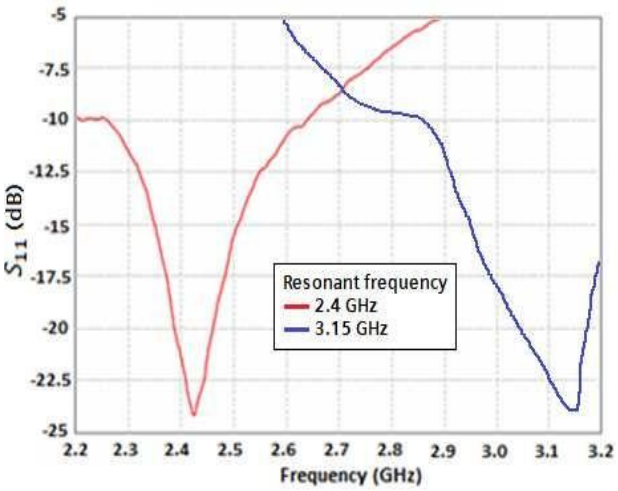


Figure7.Reflectionparametersatthefeed-pointofinvertedF-antenna, with2.4GHzand3.15GHzresonant frequencies

CONCLUSION

This study presents a concept for electronically adjusting the resonance frequency of an inverted F-antenna based on ferrite. The idea behind the suggested concept is to change the IFA antenna's resonance frequency by carefully adjusting the ferrite material's magnetic permeability. By increasing the magnetic bias from 0.2 KOrested to 6.0 KOersted, which corresponds to a 31% frequency shift, it is discovered that the antenna resonance frequency may be adjusted between 2.41 GHz and 3.15 GHz. Electronically achieving this change in resonance frequency without changing the antenna's physical size or shape significantly improves the communication system's overall performance.

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