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# Frequency Tuning OF Inverted F Antenna

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***Abstract**: Internal antennas are widely used in mobile wireless communication devices like smart phones, which have been a major incentive of internal antenna research and design during the last decade, where new designs with wider frequency bands have been introduced; single-band devices have developed into multiband and multimode terminals. Although the average terminal size has decreased drastically, the internal antennas have been designed into standard solutions, to meet the new design requirements, taking into consideration the strict limitations set on the energy absorbed by the users of mobile devices. In this paper, a model for frequency tunable ferrite-based Inverted F Antenna is proposed by altering the permeability of the ferrite material.*

## I. Introduction

There are different techniques that can be possibly used for changing the operating frequency of the antenna. They are mainly categorized as: mechanical techniques, using tunable electronic circuits, and alteration of the properties of the antenna material. In this paper we will focus on the alteration of the electrical properties (permittivity, permeability, and conductivity) of the antenna material.

The mechanical techniques, which include changing the shape or dimensions of the antenna, have a disadvantage of lack of reliability to time delay, and short life time due to mechanical movements. On the other hand the alteration of the antenna material does not require a mechanical movement of the antenna as suitable material is incorporated into the antenna such that changing its electrical properties lead to change in the antenna operating frequency[1].

**Alteration of Ferrites permeability**

Ferrites are magnetic materials made from a mixture of metal oxides. Due to their electrical characteristics; they can be used many applications like antennas, electronic and communication devices, inductors, transformers, and many other applications. Ferrites have high permeability at low frequencies, and a dielectric constant of 10 or more, besides its high resistivity. The behavior of ferrites at high frequencies is well studied in many research publications e.g. [2] & [3]. In this section a brief overview of ferrites characteristics is presented.

The magnetic dipole moment is primarily responsible for the magnetic properties of the ferrites, where it is produced by the spin of electrons in the material. Fig. 1 depicts this process where a constant magnetic field $H_0$, is applied to the ferrite, and the electrons start to spin about the axis of the magnetic field at a frequency of $\omega_0 = 2\pi\gamma H_0$ (called Larmor frequency), where $\gamma = 2.8\text{MHz/Oersted}$. When the magnetic field is intense, the electron spins causing the dipole moments are aligned together and form one large dipole moment. This case is called magnetization saturation $M_s$, which can be used as an indicator of the density of magnetic flux that is needed to align all the electron spins of the ferrite.

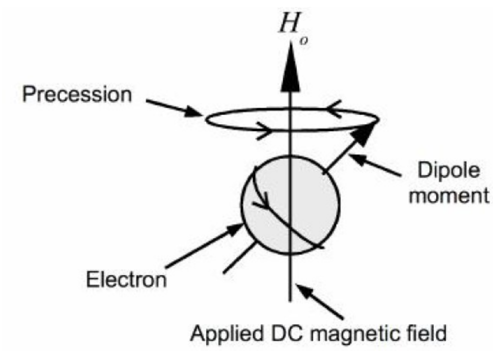


Fig. 1 Spin of electron about the constant field $H_0$.

In conjunction with the constant magnetic field $H_0$, a tiny magnitude alternating magnetic field at a radio frequency $\omega$ , can be used to produce a forced spin of magnetic moment. In this case, the Polder permeability tensor [4] is produced such as

$$[\mu] = \begin{bmatrix} \mu & j\delta & 0 \\ -j\delta & \mu & 0 \\ 0 & 0 & 1 \end{bmatrix} \quad (1)$$

where$\mu$ and $\delta$ are given as:-

$$\mu = \mu^{'} - j\mu^{"} = 1 + \frac{\omega_m(\omega_0 + j\omega_L)}{(\omega_0 + j\omega_L)^2 - \omega^2} \quad (2)$$

$$\delta = \frac{-\omega_m\omega_0}{(\omega_0 + j\omega_L)^2 - \omega^2} \quad (3)$$

where $\omega_m = 8\pi^2\gamma M_s$, and$\omega_L = \pi\gamma\Delta H$.

Ferrites are commercially obtainable including nickel, lithium, and magnesium ferrites, with different shapes including bars and sheets. The magnetization saturations of these ferrites have ranges from$300\text{ Guess} \le 4\pi M_s \le 5000\text{ Guess}$, and a resonance width from$10\ Oersted \le \Delta H \le 900\text{ Oersted}$. As we are dealing with radio frequencies, the frequencies $f_0, f_m,$ and$f_L$ are measured in MHz, where$f_0 = \gamma H_0$, $f_m = 8\gamma\pi M_s$, and $f_L = \pi\gamma\Delta H/2$.

If the polarization of the applied magnetic field$B$ and the density of the magnetic fluxHis circular, where (+) denotes clockwise and (-) denotes anticlockwise polarizations, then $B$ can be expressed in terms of $H$ as:-

$$\begin{bmatrix} B_+ \\ B_- \\ B_z \end{bmatrix} = \mu_0 \begin{bmatrix} \mu_+ & 0 & 0 \\ 0 & \mu_- & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} H_+ \\ H_- \\ H_z \end{bmatrix} \quad (4)$$

where $\mu_+ = (\mu + \delta)$, and $\mu_- = (\mu - \delta)$.

Fig. 2 depicts a characteristic performance of $\mu_+$ and $\mu_-$ versus the frequency of the RF magnetic field. It can be seen that the clockwise waves resonates at $f_0$ where of $\mu^{"}$ exhibits a significant peak can be observed at that frequency. This indicates a significant reduction in the magnitude of the clockwise waves, in contradiction with case of anticlockwise waves, where there is no attenuation. Moreover, the waves do not propagate if the frequency of the RF magnetic field lies in the range $f_0 < f < f_0 + f_m$ as the real part ($\mu^{'}$) of the ferrites permeability is negative in this case.

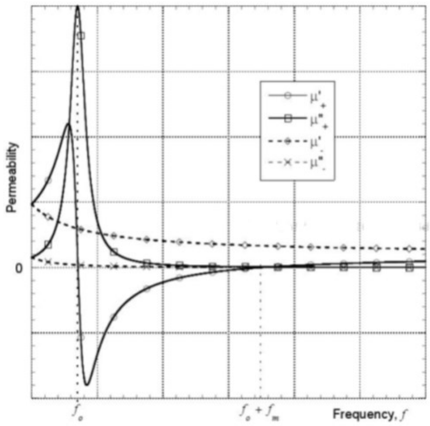


Fig. 2 Ferrites permeability as a function of the frequency of RF magnetic field.

This change in the magnetic field intensity when a radio frequency magnetic field propagates through the ferrites can be employed in designing frequency tunable antennas. In order to investigate this case, the effective permeability $\mu_{eff}$ can is used to estimate the range of frequency tuning of the ferrite material. The magnitude of $\mu_{eff}$ depends on the direction of the static field $H_0$and on the radio frequency magnetic field $H$. Here, we have three scenarios: parallel bias with $\mu_{eff} = 1$, transverse bias with $\mu_{eff} = (\mu^2 - \delta^2)/\mu$, and longitudinal bias with $\mu_{eff} = \mu \pm \delta$. In the transverse bias case $\mu_{eff}$ will be negative, and the waves will not propagate when the frequency of the RF magnetic field lies in the range $\sqrt{f_0(f_0 + f_m)} < f < (f_0 + f_m)$.

In the saturation phase of the ferrites, the following approximations hold $\mu \cong \mu_0$ and $\cong 4\pi\mu_0\gamma M_r/f$ , where $M_r$ indicates the remaining magnetization in the ferrite after the static magnetic field $H_0$is turned off [3]. Figure 3 illustrates $\delta$ versus the frequency of the RF magnetic field.

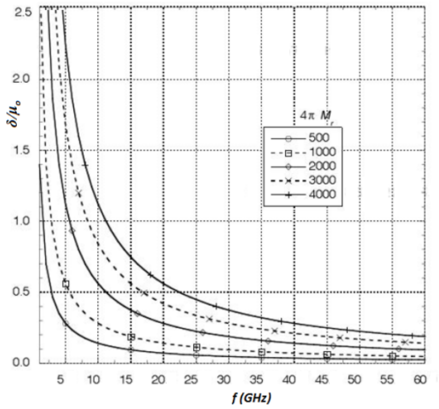


Fig. 3 Maximum range of frequency tuning of a ferrite antenna vs. frequency of RF magnetic field[1].

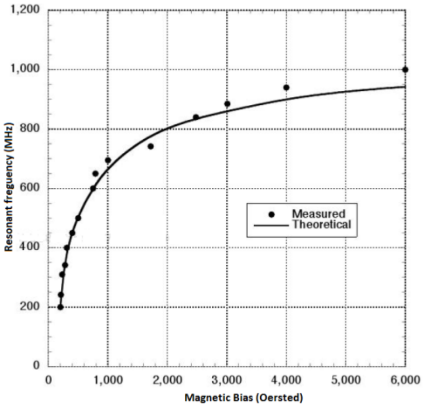


Fig. 4 Resonant frequency vs. the static magnetic field $H_0$ (Magnetic bias), for a rectangular ferrite micro-strip batch antenna[5].

As the maximum range of frequency tuning of the ferrite antenna (including micro-strip and dielectric resonator antennas) depends on $\delta$, it can be seen from Figure 3 that the maximum frequency tuning range declines by increasing the frequency of the RF magnetic field. The static field $H_0$ can be produced either by a permanent magnet or by an electromagnet with dc current. Therefore, the resonant frequency of a ferrite micro-strip batch antenna can be controlled by varying the current in the electromagnet that produces the static magnetic field $H_0$, as shown in Fig. 4[5]

**Proposed model for Ferrite-based Inverted F Antenna**

In this section a model for a ferrite-based Inverted F antenna is proposed. Figure 5 shows a typical 2.4GHz micro-strip Inverted F antenna, and Fig. 6 shows a typical radiation pattern of the antenna with vertical polarization. The reflection at the feed-point of the antenna in dB is depicted in Fig.7, where it can be seen clearly that the resonant frequency of the antenna occurs at around 2.41GH.

Fig. 5 Typical 2.4GHz Inverted F antenna

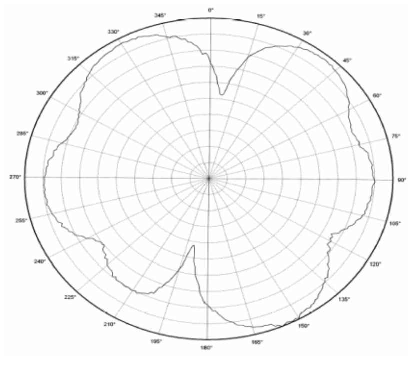

Fig. 6 Typical radiation pattern of 2.4 GHz Inverted F antennas with vertical polarization [6]

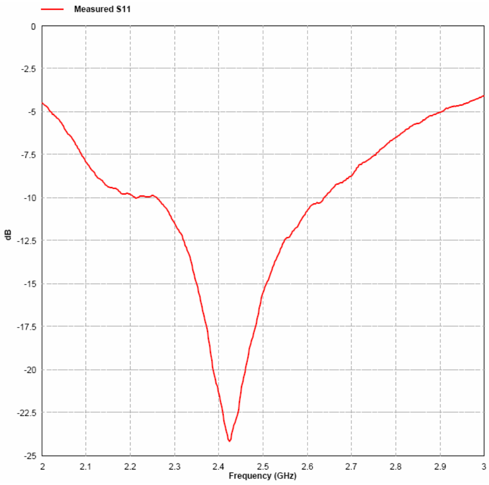


Fig. 7 Reflection at the feed-point of the 2.4GHz Inverted F antenna [6].

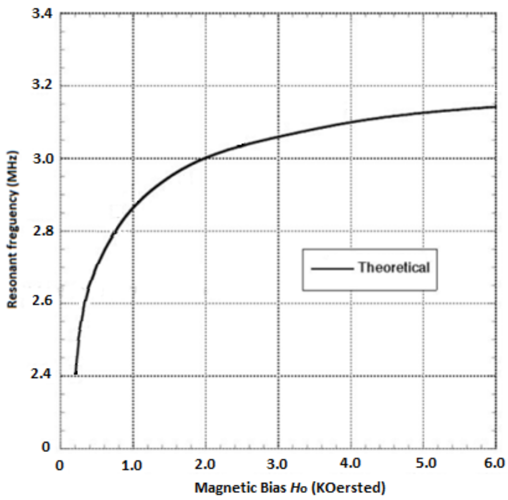


Fig. 8 Resonant frequency vs. the static magnetic field $H_0$ (Magnetic bias), for 2.4GHz Inverted F antenna.

Based on the explanations presented in section 1 and 2, the resonant frequency is expected to follow the curve shown in Fig. 8. From this figure it can be seen that the resonant frequency of the inverted F antenna can be significantly shifted from 2.41GHz to 3.15GHz by increasing the bias frequency from 0.2KOrested to 6.0KOersted, with a shift percentage of around 31%. This leads to a significant enhancement in the performance of the antenna and hence the communication systems over wide range of frequencies

## II. Conclusions

In this paper a model for frequency tunable ferrite-based Inverted F antenna is proposed. The resonant frequency of the antenna can be significantly shifted by altering the permeability of the ferrite material in the antenna, and without changing the physical dimensions of the antenna. The resonant frequency shift gives flexibility to operate the antenna over wide range of frequencies which leads a overall enhancement of the communication systems.

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