DESIGN OF A TUNABLE FEED GAP HALF-WAVE DIPOLE ANTENNA

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ABSTRACT

This paper presents a novel formula that directly relates the feed gap and frequency of operation of a half-wave dipole antenna. A tuning knob is attached to the two halves of the dipole antenna rods in this modified antenna. Turning the knob in either direction changes the feed gap of the half-wave dipole antenna. The new formula is simple enough to determine the frequency of the half-wave dipole antenna at any level of the antenna's feed gap. The modified formula reduces the rigor involved in designing a half-wave dipole antenna with a feed gap suitable for a specific frequency of radiation. The modified formula is used to generate different frequencies as the feed gap size changes. The results obtained show a reasonable impact on the frequency and, by extension, on the wavelength of the antenna. The results obtained clearly show that for a particular length of feed gap, there is a corresponding stable frequency and wavelength. The results of the design and proposed formula were validated with MATLAB simulations for the radiation pattern in E-plane which conform to the standard radiation pattern of a half-wave dipole antenna.

Keywords: feed gap, dipole antenna, tunable feed gap and frequency

1.0 INTRODUCTION

It is a well-known fact that information and communication technology are virtually the mainstay of all developed and developing economies in the world, according to (Kraus & Marhefka, 2002). The use of antennas in all communication facilities cannot be forgotten as quickly as antennas act like the eyes and ears of all modern communication installations, as also stated by (Balanis, 1982). Its applications range from satellite, broadcast, radar, both military and commercial aircraft, spacecraft, monitoring animals in the forest (for agricultural purposes), etc., according to (Pradhan & Singhal, 2020; Praise & Ifeoma, 2020).

Therefore, antennas play a very useful role in modern information technology and economic advancement. Therefore, the size of the feed has more implication in the dipole antenna design than just the radiation of electromagnetic waves. It may have an effect on one or more of the other parameters of the dipole antenna, such as its length, frequency, radius, and wavelength, as demonstrated in the designs of (Praise & Ifeoma, 2020; Mynuddin & Rahman, 2020; Gençoğlan & Çolak, 2018; Marks, 2017; Kumar, 2016; Charrier & Codalema, 2015; Tawde, 2015; Banerjee & Bezboruah, 2014).

The research work intends to investigate the impact of the variation of the feed gap have on the length and radius of a half-wave dipole antenna. The feed gap of a dipole antenna is a very crucial feature of the antenna. This is the point at which the electromagnetic radiation actually takes place in the antenna, according to (Nguyen & Park, 2013; Singh et al., 2012).

2.0 DESIGN OF THE MODIFIED HALF-WAVE DIPOLE ANTENNA

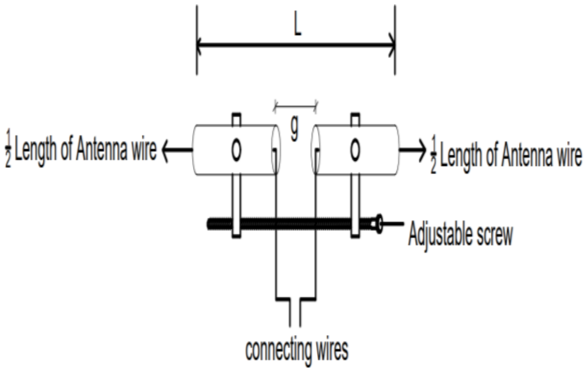

Figure 1: A Modified Tunable Feed Gap Half–Wavelength Dipole Antenna

Figure 1 is the structure of the modified half-wave dipole antenna designed such that the gap of the normal half-wave dipole antenna that is always fixed is modified in this design to provide for alteration to meet the user's demand in terms of frequency of operation without involving the manufacturers. The special feature of this modified antenna is that the feed gaps that affect the frequency of the antenna at a particular point are adjustable. This implies that the frequency is consequently adjustable to the user's advantage. It is on this principle that the modified equation (8) finds its relevance in this research work.

3.0 MODIFIED FORMULA FROM THE TUNABLE ANTENNA

The following equations for calculating the parameters of a half-wave dipole antenna (length, wavelength, feed gap, and radius) have been established in the researches of [4, 5, 6, 7, 8, 9, 10 and 11].

$$\lambda = \frac{c}{f_r} (\text{mm}) \quad (1)$$

$$g = \frac{L}{200} (\text{mm}) \quad (2)$$

$$L = \frac{142.5}{f_r} (\text{mm}) \quad (3)$$

$$r = \frac{\lambda}{1000} mm \quad (4)$$

Where,

$L =$ Length of antenna
$r =$ Radius of antenna
$f =$ Resonating frequency
$g =$ Feeding gap
$\boldsymbol{\lambda} =$ Wavelength

For the purpose of designing a tunable feed gap half–wave dipole antenna, equations (2) and (3) would be used since they contain the half–wave dipole antenna parameters required for this research work, that is the feed gap and frequency. For the purpose of this derivation of the modified formula, the length of the wire and its radius are considered constant. Then the derivation process is as follows;

From equation (2),

$$g = \frac{L}{200}$$

Let the length of the antenna be

$$L = 200g \quad (4)$$

Also, from equation (3), the length of the dipole antenna is;

$$L = \frac{142.5}{f_r}$$

By equating equation (3) with (4) recalling that L is constant and common to both equations, the length becomes;

$$L = \frac{142.5}{f_r} = 200g$$

Therefore, establishing the relationship between the feed gap and frequency, we have equation (5) as;

$$\frac{142.5}{f_r} = 200g \quad (5)$$

Making the feed gap g, the subject of equation (5), it becomes,

$$g = \frac{142.5}{200 f_r} (mm) \tag{6}$$

Equation (6) relates the feed gap and the frequency of the half-wave dipole antenna and can be used to design tunable feed gap of a dipole antennas. Another physical parameter that is also constant is the radius of the same antenna wire.
Alternatively, the operating frequency of the antenna can also be obtained as

$$f_r = \frac{142.5}{200 g} (Hz) \tag{7}$$

From equations(6), the feed gap and operational frequency could be calculated by keeping the length of the wire antenna constant. The equations also showed that the operating frequency f_r increases with a decrease in the feed gap g and vice versa.
Therefore, equations (6) could further be simplified to give equations (8) as;

$$g = \frac{0.7125}{f_r} (mm) \tag{8}$$

4.0 PRINCIPLE OF OPERATION

This antenna is based on the simple dipole antenna that we are all familiar with. It is composed of two radiating wires of equal length and radius made of the same material, such as aluminum. An adjustable spindle or tuning knob is attached to both arms of the dipole. The adjustable device is designed to control the space between the ends where the signal is fed to the antenna, otherwise referred to as the feed gap in this research work. Adjusting the tunable spindle or tuning knob varies the size of the gap separating the two poles or arms of the tunable antenna. Depending on whether the knob is turned clockwise or anticlockwise, the feed gap is either reduced or widened, respectively. As this gap is varied by this process, the frequency under which the electromagnetic wave is radiated is automatically and inversely varied in the same proportion. If the direction of tuning is clockwise, the feed gap is reduced and the frequency of operation is increased. While tuning the antenna in the anticlockwise direction, that is, widening the feed gap, the frequency will be reduced. Therefore, the frequency is inversely proportional to the feed gap of the dipole antenna. But all other general parameters of a half-wave dipole antenna, like E- and H-fields, efficiency, beam solid angle, radiated power and dissipated power, directivity, and gain, maintain their already established formulae in telecommunication engineering and remain unaltered.

5.0 THE SIMULATION SETUP

Figure 2 shows the simulation set up using Simulink to investigate the relationship between the feed gap and frequency of the tunable feed gap of a half-wave dipole antenna. The block diagram is built from equation (8), the modified equation for the modified tunable feed gap of a half-wave dipole antenna for this research work

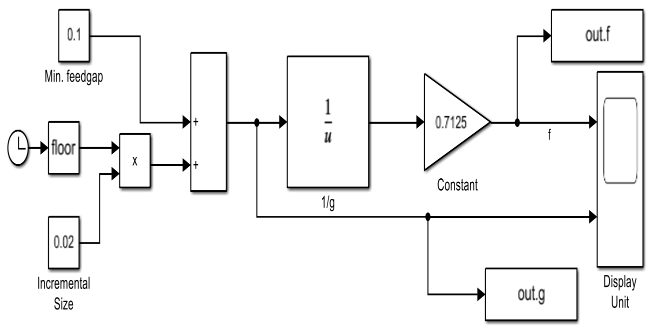

Figure 2: A Simulink Simulation Set Up

Figure 2 is a simulation setup developed using Equation (8) to accomplish this research work. The blocks with 0.1 and 0.02 are the minimum feed gap size and its incremental size. The floor is the clock input, all fed to a stereo. According to Equation (8), the output of the summer is fed to, which is the reciprocal of the frequency, and then fed to the gain. The output of the gain, which is the maintain output, is connected to an oscilloscope (display unit) where the graph showing the relationship between the feed gap and the frequency according to Equation (8) is displayed. The blocks labeled "out.f." and "out.g." in the setup represent the frequency and gain outputs, respectively.

6.0 RESULTS

The result obtained is presented as X and Figures 3 and 4 below**.**

Table 1. Results of Impact of Feed Gap on Frequency

This table presents the mathematical computation of using the modified equation (8)

X = [g, f]: [0.01, 71.25; 0.02, 35.63; 0.04, 17.81;
0.06, 11.88; 0.08, 8.91; 0.1, 7.13; 0.2, 3.56; 0.4, 1.78; 0.6, 1.19; 0.8, 0.891; 1,0. 713]

X is the function of feed gap and frequency, with the results obtained by varying the feed gap of the modified tunable feed gap of a half-wave dipole antenna. The table is formed using the computational results of the modified formula in equation (8). Also, the corresponding values of frequency obtained are recorded in the table. The results show that as the feed gap increases, the frequency decreases.

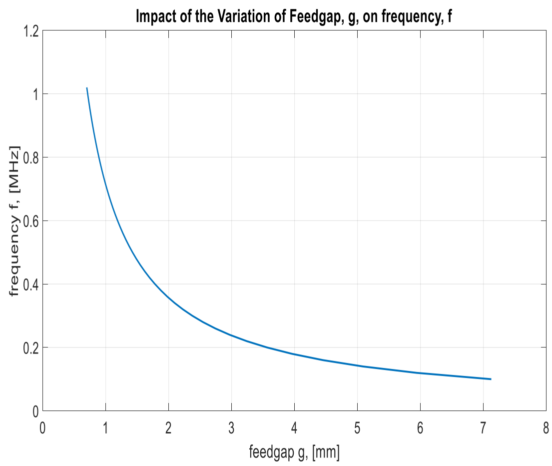

Figure 3. Graph of Feed Gap against Frequency

Figure 3 is a graph of feed gap against frequency obtained using the Simulink setup of Figure 2. The graph shows that as the tunable feed gap of the half-wave dipole is increased, the frequency decreases. This also attests to the fact that in Equation (8), the feed gap is inversely proportional to the frequency of the antenna.

Figure 3 is the graph of the variation of the feed gap with frequency. The graph showed that as the feed gap of the modified half-wave dipole antenna is varied progressively, the frequency reduces. The result presented on Table 1 also confirmed it. Figure 4 shows the radiation pattern of the modified tunable feed gap of a half-wave dipole antenna.

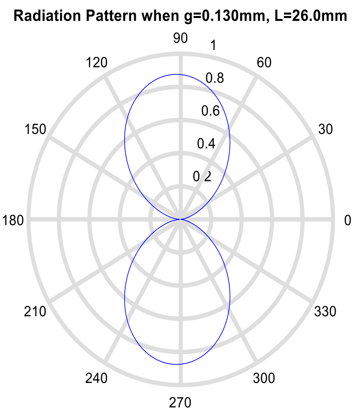

Figure 4. E-Field of the Tunable Feed Gap half-wave Dipole Antenna in the E-plane

7.0 CONCLUSION

The main aims of this research are to design a modified half-wave dipole antenna with a tunable feed gap and provide a modified formula that will relate the feed gap with the frequency of operation of the modified antenna. A half-wave dipole antenna was selected because of its popularity and wide range of applications. From the results obtained, the feed gap is inversely proportional to the frequency of the antenna, thereby establishing a direct relationship in one formula between these two parameters of a half-wave dipole antenna. But it was observed that the radiation pattern of the modified half-wave antenna and its equation, as shown from the results obtained, are hereby presented for practical application.

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