A Novel Defected Ground Structure Microstrip Patch Antenna for STM-1 and Cellular Mobile applications at 4.9 GHz and 7.6 GHz

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Abstract- Microstrip antennas have numerous advantages such as small size, low fabrication cost, light weight and can be easily installed in the systems and it finds its applications in various systems like aircraft, satellite and spacecraft. But it has drawback of narrow bandwidth. To overcome this drawback, Microstrip Antennas with Defected Ground structure can be used. In this paper, a microstrip patch antenna with Defected Ground Structure (DGS) and its effect has been discussed. The dual band is achieved in this design and the antenna operates at 4.9 and 7.6GHz. The defected ground structure (DGS) reduces the antenna size and mutual coupling between two antennas. Moreover, it reduces the harmonics of the antenna. The design is simulated on CST Microwave Studio 2010 Software. Finally, the results obtained from the simulation are demonstrated.

Index Terms- VSWR (Voltage Standing Wave Ratio), STM (Synchronous Transport Module), Return loss, Directivity

1. INTRODUCTION

Antenna is defined as a device or a transducer which transforms an RF signal into electromagnetic waves and acts as a means to transmit and receive radio waves. Microstrip antennas have gained a lot of popularity due to their salient features such as low profile, simple and inexpensive to design and manufacture, flexible in terms of configuration, polarization, pattern, resonant frequency and impedance when a particular shape and mode are selected [1]. These antennas are used in various applications for example, in satellite communication, in handsets and base stations for mobile communication, in telemetry antennas for missiles and so on. Microstrip antennas cover a broad frequency spectrum from 100 MHz to 100 GHz, thus possess several advantages as compared to conventional antennas including robustness when mounted on rigid surfaces, easily fabricated on linear as well as planar arrays, integration with microwave integrated circuits and compatibility with MIMC design. A microstrip antenna consists of a conducting patch of any geometry on a ground plane and separated by a dielectric substrate. The rectangular and circular patches are most common geometry used in microstrip antennas. Rectangular patches are chosen as they are very simple to analyze and circular patches are chosen due to their symmetric radiation pattern. Various mathematical models have been developed for these antennas and the papers and articles published on them show their popularity among researchers. [2]

A Defected Ground Structure (DGS) is defined as an etched lattice shape composed by etching defects in the backside metallic ground plane under a microstrip line. The widely used DGS cell is realized by two wide defected areas and a narrow connecting slot of any shape such as H shape narrow at middle or U shape with narrow at bottom. It is called Defected Ground Structure because a defect has been placed in the ground plane. DGS disturbs the shield current distribution in the ground plane due to the defect in the ground. This disturbance caused by DGS changes the characteristics of a transmission line such as line inductance and capacitance [3]. Thus, any defect etched in the ground plane of the Microstrip antenna leads to the increasing effective capacitance and inductance.

In this paper, a microstrip patch antenna with Defected Ground Structure (DGS) is designed, simulated and analyzed. The rest of the paper is organized as follows: Section II gives an overview of the system model. Section III describes the mathematical analysis of the system using Transmission Line model. In section IV, the dimensions and design of proposed antenna is presented. In section V, the simulation results are presented. Section VI describes the parametric analysis to optimize the antenna. Finally, section VII concludes the work and possible directions of future work are discussed.

2. SYSTEM MODEL

Microstrip patch antenna as shown in Fig. 1 consists of two parallel conductors – a thin metallic patch and the ground plane, which are separated by dielectric substrate. The patch can take any geometry i.e. rectangular, circular, elliptical, triangular or dipole but rectangular patch is used as it is easy to analyze. This patch when excited in fundamental mode gives pattern maximum and maximum directivity normal to the patch i.e. broadside [4].

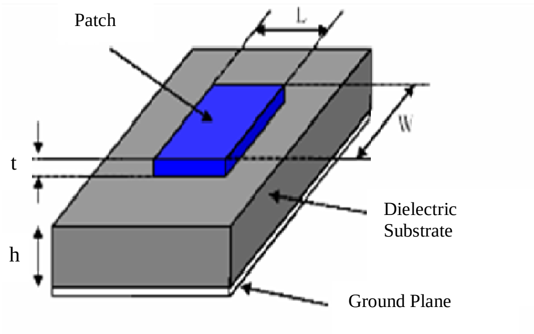

Fig. 1. A basic Microstrip Patch Antenna.

3. MATHEMATICAL ANALYSIS USING TRANSMISSION LINE MODEL

The microstrip antenna using transmission model is designed in the following method [5]:

3.1. *Calculation of the Width*

For an efficient antenna, a practical width that leads to good radiation efficiency is given by eqn. (1),

$$W=\frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}}=\frac{v_0}{2f_r}\sqrt{\frac{2}{\varepsilon_r+1}} \qquad (1)$$

3.2. *Calculation of the effective dielectric constant*

The effective dielectric constant is given by eqn. (2),

$$\varepsilon_{reff}=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2} \qquad (2)$$

3.3. *Calculation of the length extension*

The normalized extension of length is given by eqn. (3),

$$\frac{\Delta L}{h}=0.412\frac{\left(\varepsilon_{reff}+0.3\right)\left(\frac{W}{h}+0.264\right)}{\left(\varepsilon_{reff}-0.258\right)\left(\frac{W}{h}+0.8\right)} \qquad (3)$$

3.4. *Calculation of the length of patch*

The actual length of patch can be determined by eqn. (4),

$$L=\frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\mu_0\varepsilon_0}}-2\Delta L \qquad (4)$$

The length L_g and width W_g of ground is given by:

$$L_g=6h+L \qquad (5)$$

$$W_g=6h+W \qquad (6)$$

4. ANTENNA DESIGN

Based upon transmission line model the antenna is designed using following parameters mentioned in table 1:

Table 1. Dimensions of The Proposed Antenna

Substrate thickness	1.06 mm
Length of patch	14 mm
Width of patch	19 mm
Length of ground L_g	28.6 mm
Width of ground W_g	23.6 mm
Length of slot 1 in ground	1.5 mm
Width of slot 1 in ground	13.35 mm
Length of slot 2 in ground	9.75 mm
Width of slot 2 in ground	3.6 mm
Length of feed L_f	7.3 mm
Width of feed W_f	2 mm

The front view and the back view of the designed antenna is shown in Fig. 2 and Fig. 3 respectively.

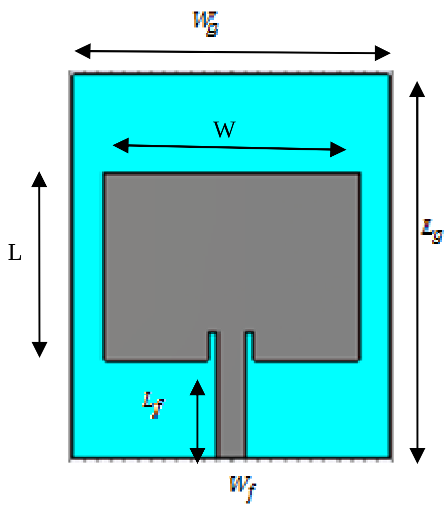

Fig. 2. Front View of proposed antenna

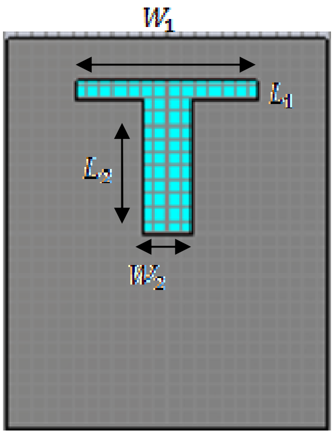

Fig. 3. Back View of proposed antenna

5. RESULTS AND DISCUSSION

The designed antenna is simulated using CST MSW 2010 and following results are obtained as follows:

5.1. *Return Loss and Bandwidth*

The return loss is a variable in which the power does not return in the form of reflection and is lost to the load [6]. The designed antenna resonates at 4.9 GHz and 7.6 GHz frequencies respectively. The return loss for 4.9 GHz is -12.75 dB and the return loss for 7.6 GHz is -13.01 dB which covers the minimum required value of return loss of -10 dB. The Bandwidth covered under first and second band is 175MHz and 159. 8 MHz respectively. The plot for Return Loss is shown in Fig. 4.

5.2. *Smith Chart*

The Smith Chart plot represents that how the antenna impedance varies with frequency. The value of impedance should lie near 50 ohms in order to perfectly match the port with the antenna. The two circles represent the two resonant frequencies i.e. 4.9 GHz and 7.6 GHz. The Smith Chart for the proposed antenna is given in Fig. 5.

5.3. *VSWR*

The VSWR (voltage standing wave ratio) plot for the design antenna (Microstrip feed) is shown in Fig. 6. The value of VSWR is 1.5833 at resonating frequency 4.9 GHz. A VSWR of 1:1 means that there is no power being reflected back to the source. At a VSWR of 2.0, approximately 10% of the power is reflected back to the source [7]. Not only does a high VSWR mean that power is being wasted, the reflected power can cause problems such as heating cables or causing amplifiers to fold-back. Here VSWR lies in range of 1-2 which is required for the satisfactory performance.

5.4. *Directivity*

The Directivity plot as shown in Fig. 7 represents amount of radiation intensity i.e. is equal to 6.028 dBi. The antenna radiates more in a particular direction as shown in polar plot, as compared to the isotropic antenna which radiates equally in all directions, by an amount of 6.028 dBi.

5.5. *Current Distribution*

Basically the current distribution shows the current intensity. It should be maximum at the centre of the patch and minimum at the the edges. The current distribution of the proposed design is shown in Fig. 8.

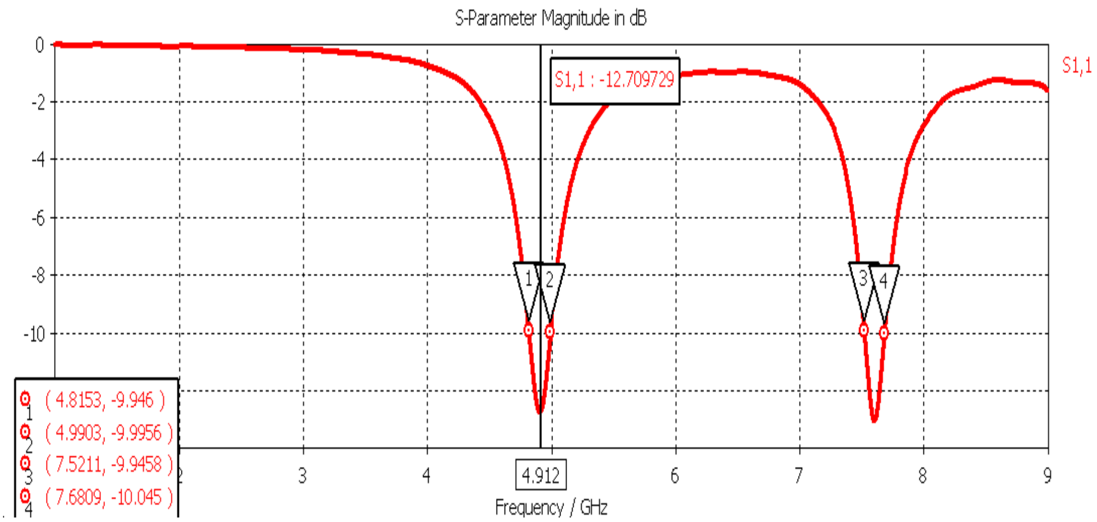

Fig. 4. Return Loss [S_{11}] at 4.9GHZ and 7.6 GHz

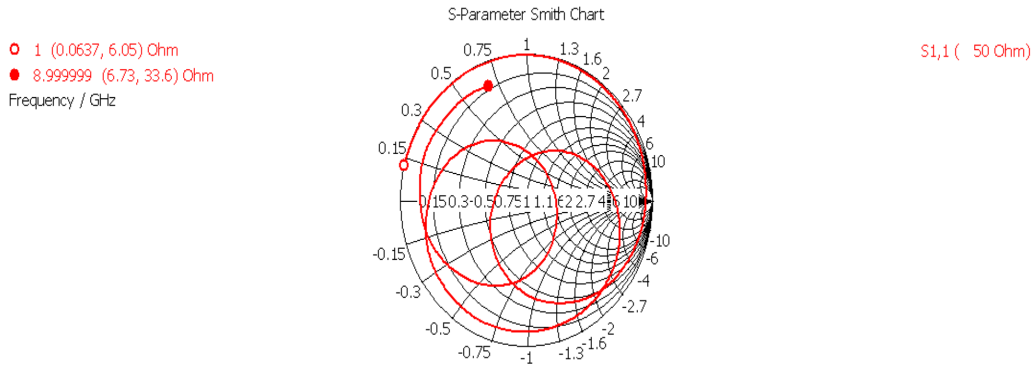

Fig. 5. Smith Chart

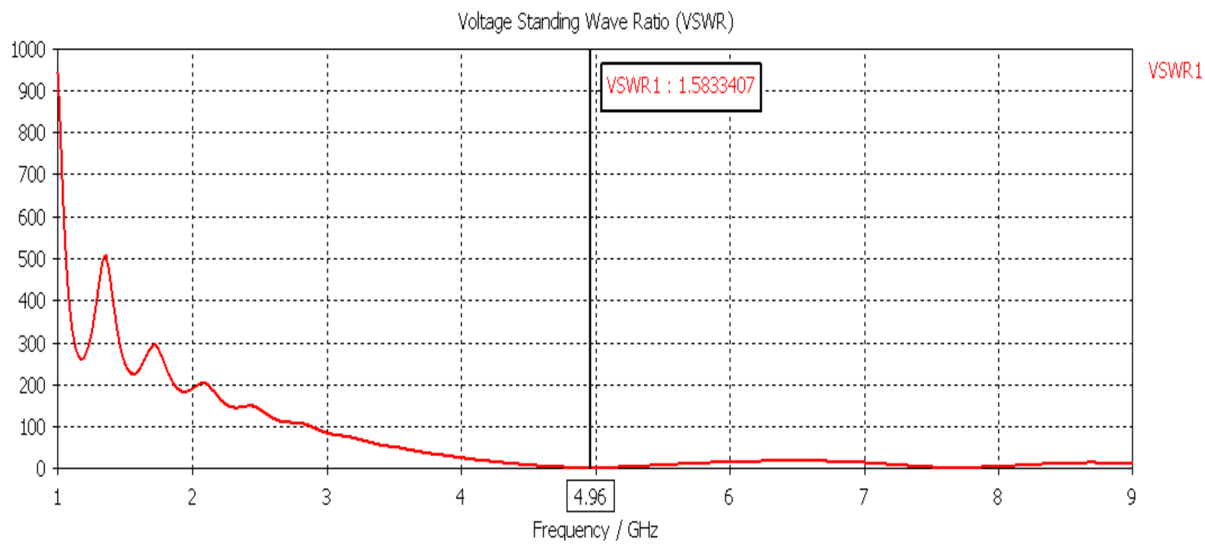

Fig. 6. VSWR at 4.9 GHz

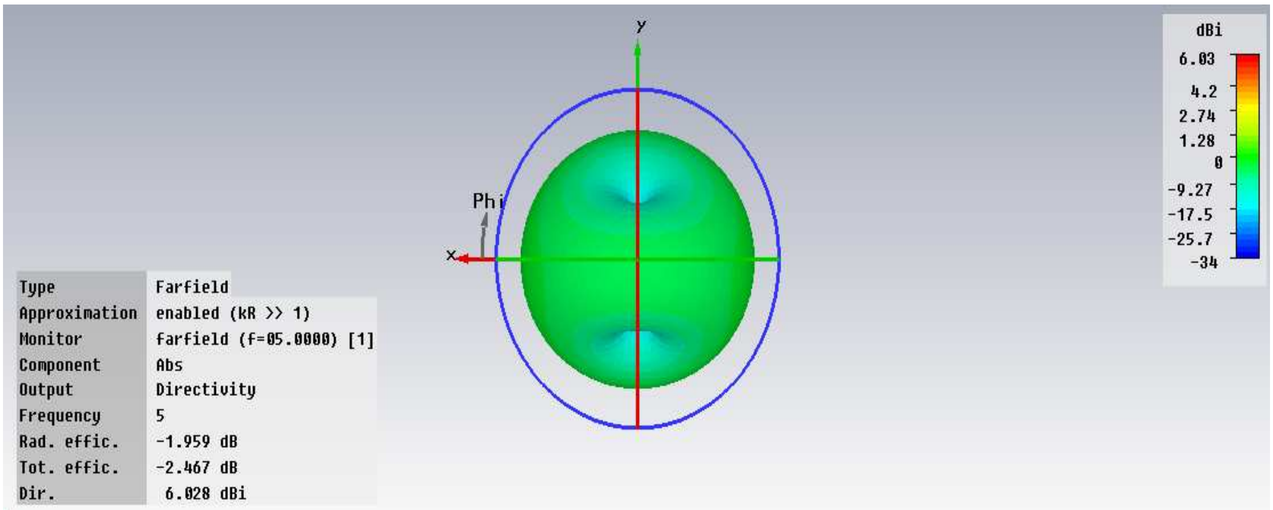

Fig. 7. Directivity plot at 5 GHz

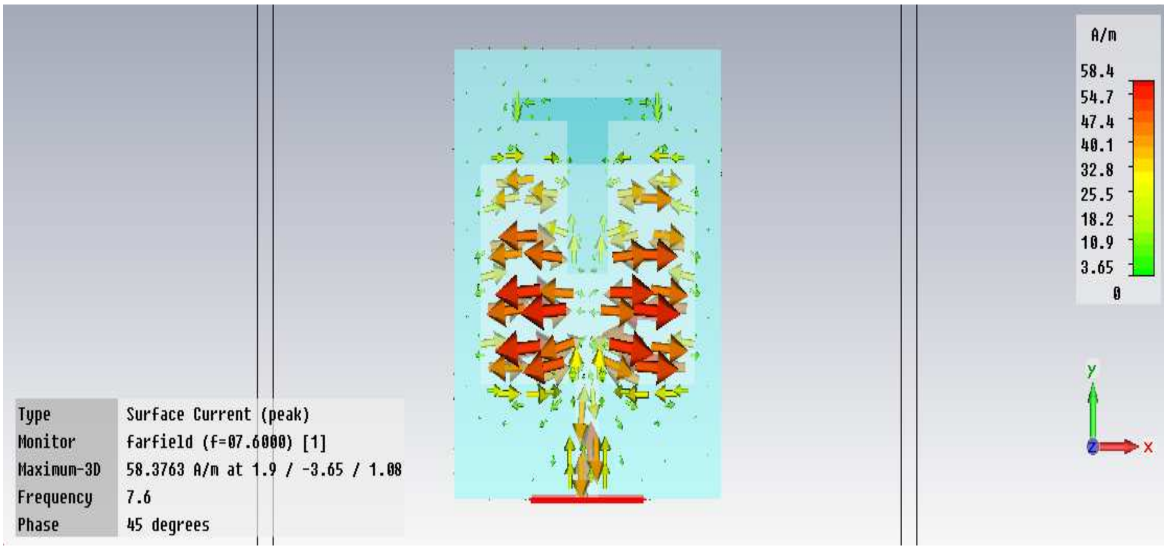

Fig. 8. Current Distribution

6. ANTENNA OPTIMIZATION

The effect of the various physical parameters like patch length, slot length, feed line dimensions etc are studied, by varying one parameter at a time and keeping all other parameters constant so that one can get an optimized antenna for the desired applications.

6.1. *Effect of varying Slot Width*

The slot length shows the coupling level of the antenna and it also shows the level of back radiation. Therefore, slot should be cut in a proper way so that impedance matching should be maximum [8]. The effect of varying slot length on return loss is as shown below in Fig. 9 that the maximum return loss i.e. around -24 dB is obtained at 2.8 mm. Hence this value of width of feed line is considered for the design to obtain the optimum value of return loss.

6.2. *Effect of varying Stub Length*

Feed line should be chosen in such a way so that there is a good impedance match between the generator impedance and the input impedance of the patch element [9]. For maximum coupling, it should be placed perpendicular to the slot. The effect of varying length of the feedline is shown in Fig. 10.

Figure 1.

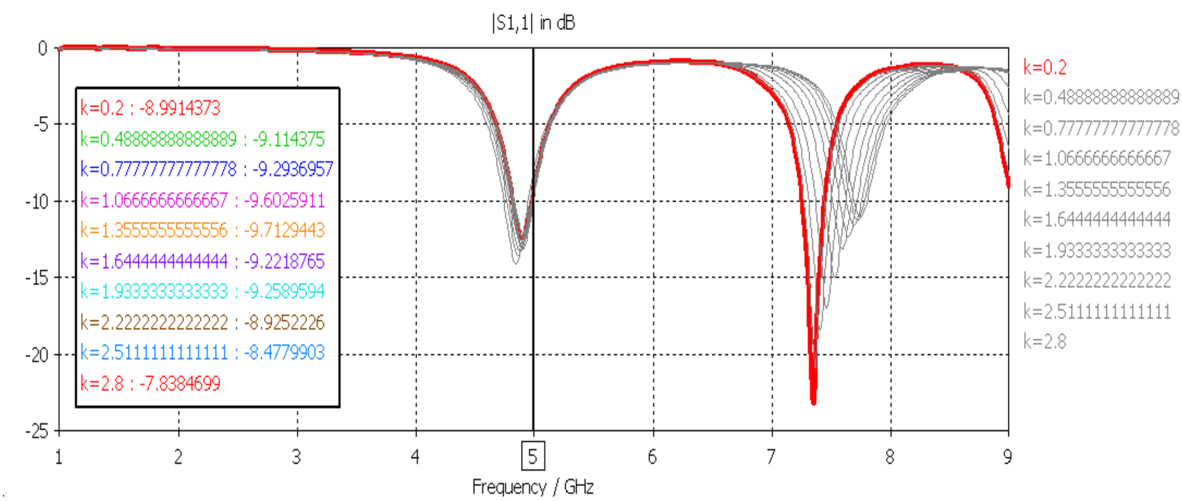

Fig. 9. Variations in S_{11} with slot length in ground plane

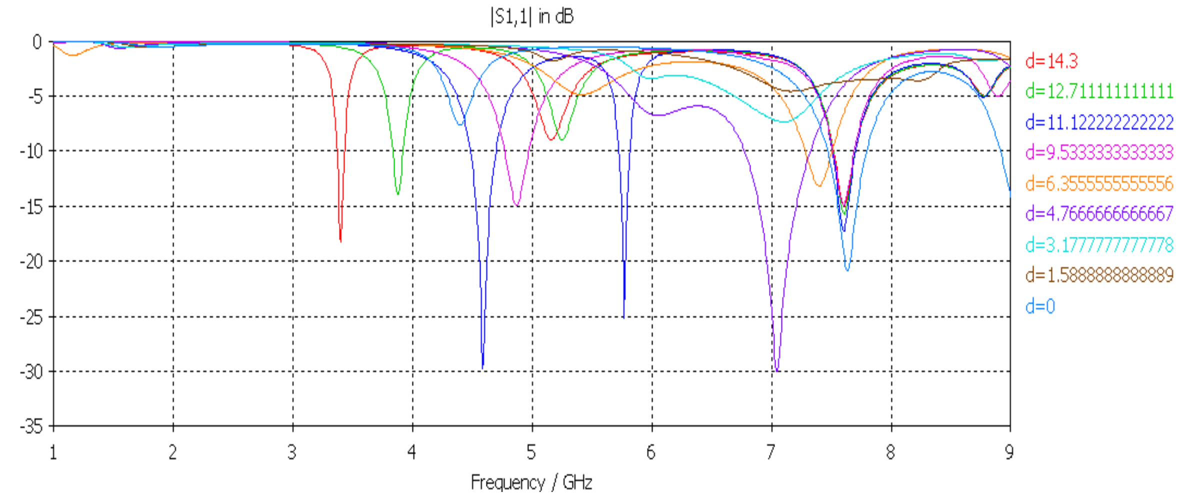

Fig. 10. Variations in S_{11} with stub length

7. CONCLUSION

A dual band microstrip patch antenna with Defected Ground Structure (DGS) and Microstrip feeding technique has been successfully designed according to design specifications mentioned in Table 1, simulated and analyzed. The first band has resonant frequency 4.9 GHz and bandwidth is 175 MHz with return loss -12.75 dB. The resonant frequency of second band is 7.6 GHz and bandwidth is 159.8 MHz with return loss -13.01 dB. The performance of the antenna meets the desired requirements in terms of return loss and VSWR at the desired operating frequency.

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