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Attenuation of EM Waves Emitted from Inset Feed Type Microstrip Rectangular Patch Antenna by Wet Snow

Highlights

- *Microstrip patch antenna*
- *Inset feed technique*
- *Attenuation of EM waves*
- *Effect of snow and wet snow to attenuation*
- *S11 measurement on Nano VNA*

Graphical Abstract

EM waves emitted from antennas are attenuated when they encounter water, snow, or melty snow. In this study, both a new antenna is designed and built and the attenuation is measured.

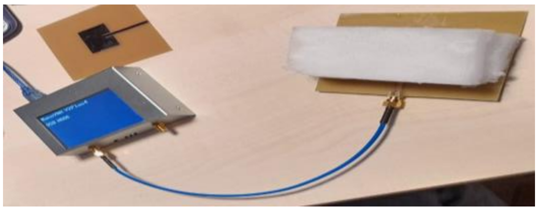

Figure. Measurement with snowy antenna

Aim

Designing a microstrip antenna and measuring EM attenuation because of snow.

Design & Methodology

Antenna is created with the help of theoretical studies and CST program and measurements are made with Nano VNA in different snow types.

Originality

EM attenuation due to wet snow is detected with Nano VNA for the first time.

Findings

The S11 value measured as -18.48 dB in the open air decreased to -4 dB in the presence of snow.

Conclusion

Wet snow causes more EM wave attenuation than dry snow.

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Islak Kar Sebebiyle İçten Besleme Tipi Mikroşerit Dikdörtgensel Yama Antenden Yayılan EM Dalgalarının Zayıflaması

Araştırma Makalesi / Research Article

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ÖZ

Mikroşerit yama antenler, düşük maliyetleri, küçük boyutları ve kolay imalatları nedeniyle öne çıkmaktadır. Bu çalışma, 2.6 GHz frekansında işlev gören bir mikroşerit dikdörtgensel yama antenin tasarımını ve farklı hava koşullarının anten üzerindeki etkisini göstermektedir. CST programında anten tasarımı ve laboratuvarda antenin imalatı sonrasında istenilen frekans ve desibel seviyesinde ölçüm yapılmıştır. Bu uygulama, VNA ile yapılan normal ölçümlerin dışında, farklı kar tipleri ile birlikte yapılan deneyleri ve sonuçları da içermektedir. Tasarlanan mikroşerit yama antenin, merkez frekansta, -18.48 dB olarak iyi bir S11 saçılma parametresi değeri elde edilmiştir. Anten üzerinde zayıflama ve termal etkiler nedeniyle ıslak kar olduğu durumlarda bu değer -5 dB civarına düşmüştür. Antenden kar kaldırılsa da karın bıraktığı ıslaklık nedeniyle eski S11 değeri tekrar elde edilememiştir ve yaklaşık -14 dB'ye ulaşılmıştır. Sonuç olarak, elektromanyetik dalgaların zayıflaması ıslak kar gibi farklı koşullar altında nano VNA ile yapılan araştırmalara göre ilk kez test edilmiş ve literatürdeki bilgilere göre uyumlu sonuçlar alınmıştır. Islak kar ve su ile olan zayıflama, içinde boşluklar bulunan kuru kara göre daha fazladır.

Anahtar Kelimeler: Zayıflama ve termal etki, kar ve ıslaklık, mikroşerit yama anten, nano VNA ölçümü.

Attenuation of EM Waves Emitted From Inset Feed Type Microstrip Rectangular Patch Antenna by Wet Snow

ABSTRACT

Microstrip patch antennas stand out because of their low cost, smaller size and easy fabrication. The study presents the design of a microstrip rectangular patch antenna operating at 2.6 GHz frequency and the effect of different weather conditions on the antenna. During the antenna design on CST program and manufacturing in the laboratory, it is aimed to perform the measurement at the desired frequency and decibel level. The study includes experiments and results made on different types of snow, apart from the normal measurement with the VNA. A good S11 scattering value was obtained at the desired frequency in the designed microstrip patch antenna as -18.48 dB. This value decreased to around -5 dB when there was wet snow on the antenna due to attenuation and thermal effects. If the snow was removed from the antenna, the old S11 value could not be returned because of the wetness left by the snow, and it remained at approximately -14 dB. Consequently, the attenuation of the electromagnetic waves have been confirmed by the literature under different conditions as wet snow with nano VNA for the first time. Attenuation by wet snow and water is greater than dry snow with voids.

Keywords: Attenuation and thermal effects, snow and wetness, microstrip patch antenna, nano VNA measurement.

1. INTRODUCTION

Microstrip patch antennas are divided into types according to their feeding type. Inset feed technique is one of these types [1-2]. Its reliability is better than others and ease of fabrication & impedance matching are really easy [3-4]. The design stages have been applied and realized by different researchers until today [5-7]. Antenna, which is one of the basic elements of wireless communication, can be used with various devices for various applications [8-10]. While EM signals coming to or emanating from antennas to perform their functions, they undergo various attenuation according to weather conditions [11-14]. Atmospheric attenuation can be caused by fog, haze, rain, hail or snow [15]. Humidity in the atmosphere or on the antenna can also cause EM wave power reduction.

In this study, inset fed microstrip rectangular patch antenna operating at 2.6 GHz frequency was made on FR4 substrate; theoretical studies and simulations were carried out in a computer program; tested with Nano VNA with SMA connector after PCB produced; then, the antenna was tested again under snowy conditions, keeping other parameters constant. Studies found in the literature have been largely validated, and particularly attenuation with wet snow and humidity has been proven.

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2. MATERIAL and METHOD

Microstrip rectangular patch antenna produced on a 1.6 mm thick (h) double-layer FR4 substrate using inset feed technique is connected to Nano VNA with SMA connectors (3.5 mm) and SS405 phase stable cable. The thickness of the conductive layer is 0.035 mm (t) and the dissipation factor is 0.019 ($\tan\delta$). Antenna dimensions can be calculated as

$$W = \frac{c}{2f_0}\sqrt{\frac{2}{\varepsilon_r+1}}, \quad (1)$$

$$L = L_{eff} - 2\Delta L\ . \quad (2)$$

c is speed of light, f_0 is operation frequency, 2.6 GHz, and ε_r is dielectric constant [1-2]. L_{eff} (effective length), ΔL (length of fringe) and ε_{ref} (effective dielectric length), which is necessary to have, can be found as

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{ref}}}, \quad (3)$$

$$\Delta L = 0.412h\frac{(\varepsilon_{ref}+0.3)(\frac{W}{h}+0.264)}{(\varepsilon_{ref}-0.258)(\frac{W}{h}+0.8)}, \quad (4)$$

$$\varepsilon_{ref} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[\frac{1}{\sqrt{1+\frac{12h}{W}}}\right]. \quad (5)$$

Under these conditions, W=37.44 mm and L= 27.44 mm. All other dimensions including inset feed are given in Figure 1 [1-2].

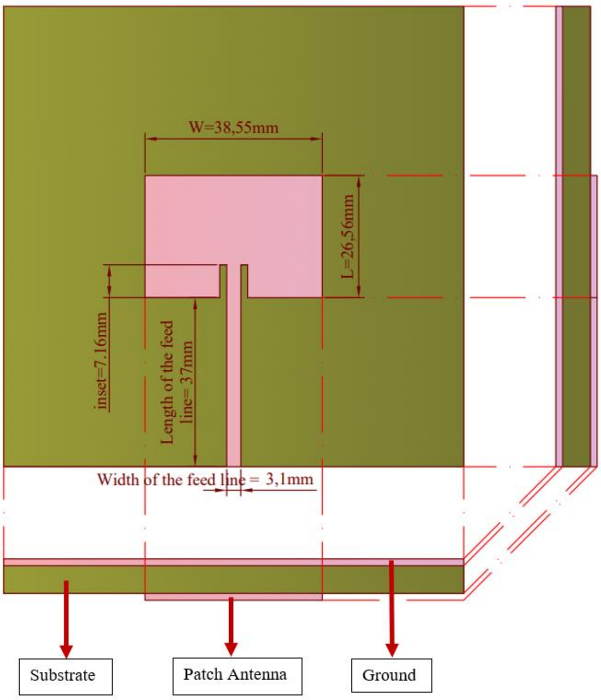

Figure 1. Dimensions of the antenna

The system for which the method of measuring the scattering parameter S11 will be applied testing under normal conditions and wet snow.

Measurements below -10 dB will indicate good operability of the antenna.

3. DESIGN, SIMULATION and MEASUREMENT

To start the design, Antennas tab was selected from the Microwaves & RF/Optical section of the CST Studio Suite program. Worked in broadband and time domain. 2.6 GHz is set as the center frequency. Antenna input is set to 50 ohms for impedance matching and port for SMA is added.

The graph of S11 [dB] for the antenna created by using the W and L lengths obtained as a result of the formulas is as in Figure 2. Since there are leftward shifts from the 2.6 GHz center frequency, the length values have been fine-tuned. The new W=38.55 mm and L= 26.56 mm. The new graph of S11 is shown in Figure 3.

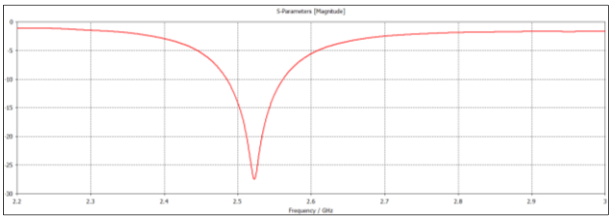

Figure 2. S11 [dB] and frequency [GHz] graph for the antenna

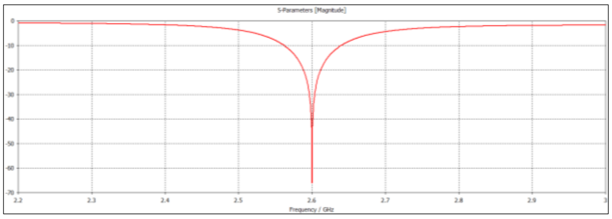

Figure 3. S11 [dB] and frequency [GHz] graph for the antenna after fine-tuned

While the minimum S11 value in Figure 2 was -27 dB, the minimum value drawn to the desired center frequency by fine adjustments decreased to under -60 dB S11 value in Figure 3. Computer measurements and real measurements made in the laboratory do not fully overlap with each other in RF circuits. For this reason, the more perfect computer graphics are obtained, the better the actual graphics will be.

Figure 4 (a) shows the S11 graph of a microstrip rectangular patch antenna measured with nano VNA under normal conditions in the laboratory. Its minimum value is -21.432 dB at 2.58 GHz but at 2.6 GHz working frequency, the value is -18.48 dB. Figure 4 (b) gives the Smith chart of the produced antenna. It can be seen that the Marker 2 (means operating frequency) is very close to the midpoint of the Smith chart, 50 ohms. In such cases, close to 50 ohms is of great importance for impedance matching. In Figure 4 (c), the other figure of merits values can be seen Marker 1 to Marker 3.

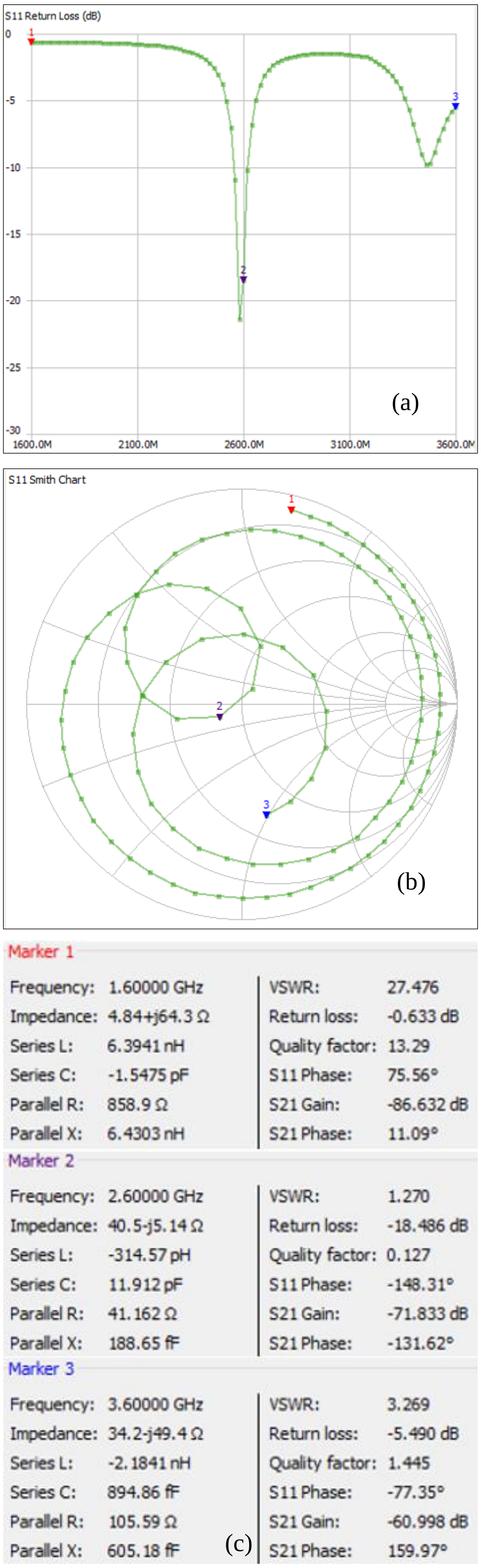

Figure 4. (a) S11 [dB] and frequency [MHz] graph for the antenna with nano VNA under normal conditions in the lab (b) Smith chart of the antenna with nano VNA under normal conditions in the lab (c) values of antenna parameters for different markers

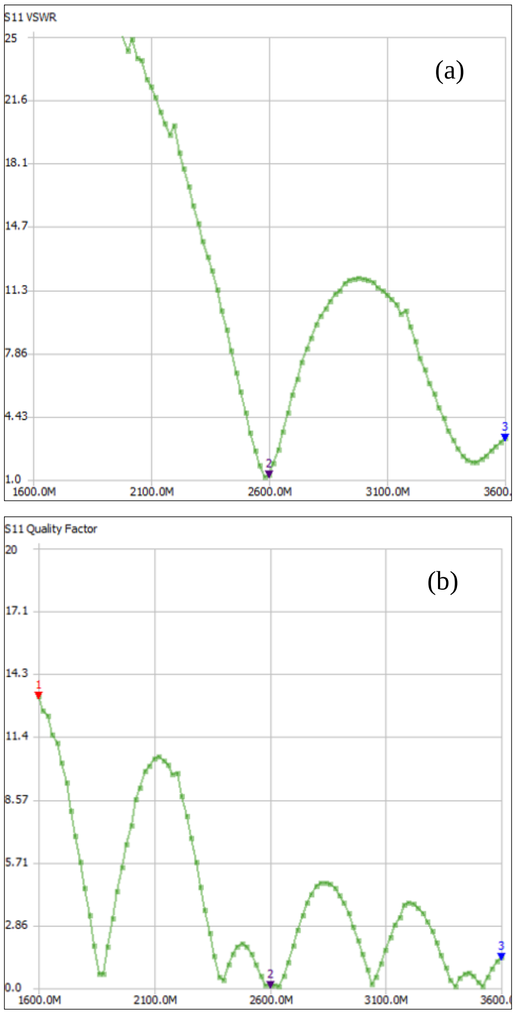

Figure 5. (a) VSWR (b) Quality factor graphs for the antenna with nano VNA

The VSWR graphic value close to 1 (1.27), which is considered quite good, and the quality factor graph, which is predicted to work quite appropriately close to 0 (0.127), are given in Figure 5 at the desired operating frequency.

Now, the result of the measurement made by placing dry snow on the antenna (Figure 6.a, -5.3 dB), the result of the measurement made by taking the dry snow but when there is wetness and wet snow patches (Figure 6.b, -14 dB), and the measurement result made with snow again but at this time wet and melted snow (Figure 6.c, -4 dB) will be shared, respectively.

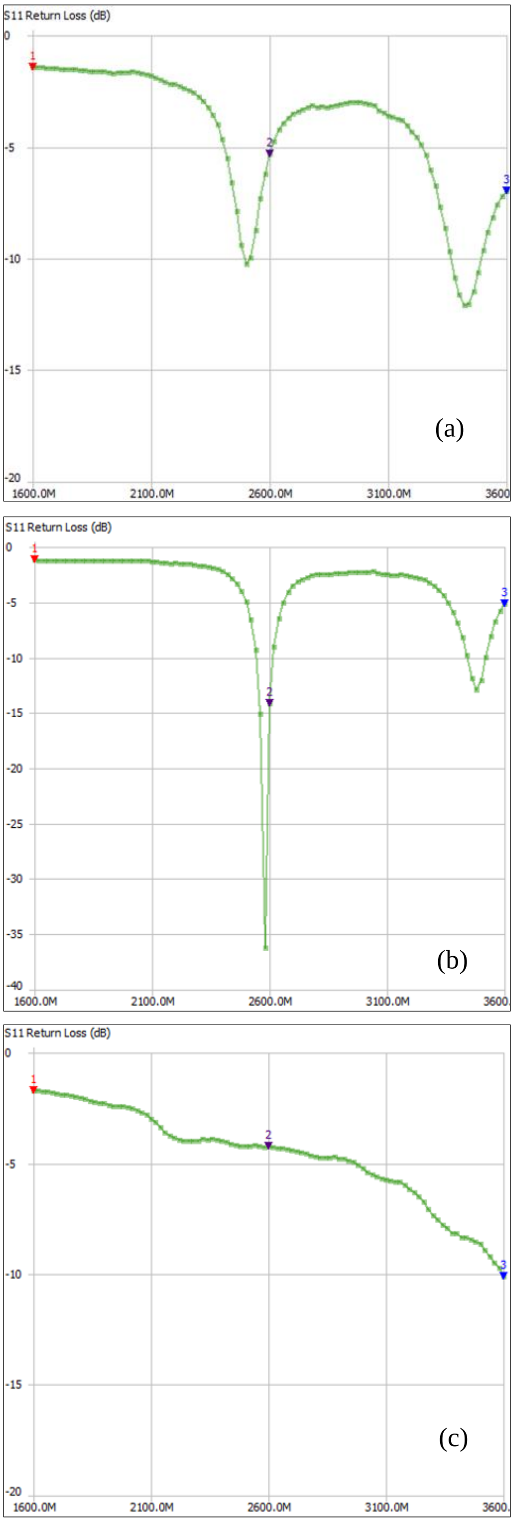

Figure 6. S11 [dB] and frequency [MHz] graphs for different conditions (a) snow on the antenna (b) removed snow but wetness and melted snow patches on antenna (c) second measurement with wet and melted snow

Thus, it is shown that fog, haze, rain, cloud, polluted weather ect. conditions in the atmosphere [11-15], as well as snow and wet snow cause electromagnetic wave attenuation [16-17].

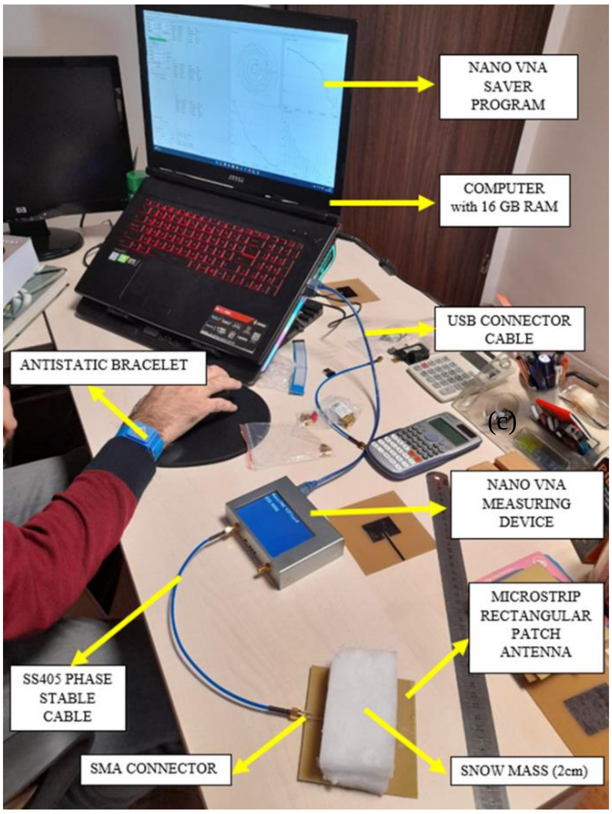

Figure 7. Laboratory measurement

In Figure 7, the measurement photograph of the nano VNA and microstrip rectangular patch antenna in the laboratory is given. Snow mass, connection equipment, antistatic wristband and computer running nano VNA Saver program are also shown.

4. RESULTS AND DISCUSSION

The S11 value, which was approximately -22 dB in the computer program, was reduced below -60 dB with minor changes in antenna dimensions, but -18.48 dB was measured with nano VNA in real environment conditions in the lab. measurements.

Measurements made under snow were more than 10 dB effective and the S11 value was measured as -5.3 dB. When snow is taken over the antenna again, -14 dB S11 is obtained. When snow was added on the antenna again, it reached -4 dB levels as shown in Figure 6, the obtained results are similar as the literatures [16-19] in terms of attenuation.

Impedance matching is set to 50 ohms and 50 ohm sensitive SMA connectors are used in the actual measurement. The impedance is 40.5 - j4.15 ohm in the lab. experiment. The cables used are quite short (30 cm) and their possible affects for attenuation are very little.

5. CONCLUSION

Electromagnetic wave attenuation due to rain, fog, haze, dust cloud or snow has been studied in the literature.

The attenuation of waves emitted from antennas was clearly seen in this work by lab experiments. While dry snow is not effective in weakening, wet snow is an important factor in deterioration. So much so that even when the snow is removed from the antenna, the old S11 value cannot be reached due to its wetness and thermal values. When snow is added again, a worse result is reached. In this case, it can be said that the main deterioration is caused by water and wet snow not dry snow with void.

6. FUTURE WORKS

It is planned to test the same antenna in an environment created using an electronic device that gives an artificial fog effect, and in a real fog environment.

DECLARATION OF ETHICAL STANDARDS

The author of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission

AUTHORS' CONTRIBUTIONS

Rabia ÖZKAN: Performed the design, simulation, implementation and experiments, carried out the measurements, reported the results.

Oğuzhan MERT: Performed the design, simulation, implementation and experiments, carried out the measurements, reported the results.

Yusuf YILMAZ: Performed the design, simulation, implementation and experiments, carried out the measurements, reported the results.

Feyza RAMAZAN: Performed the design, simulation, implementation and experiments, carried out the measurements, reported the results.

Mehmet DUMAN: Performed the theoretical studies, literature research, design, simulation, implementation and the experiments, carried out the measurements, analyzed the results. Managed the writing process of the article.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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