Performance modelling of a cost effective COTS UHF Log-periodic antenna

C. Blaauw
Defence and Security Cluster
CSIR
Pretoria, South Africa
cblaauw@csir.co.za

J.E. Cilliers
Defence and Security Cluster
CSIR
Pretoria, South Africa
jcilliers@csir.co.za

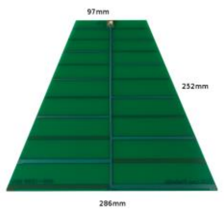
***Abstract*—Commercial off the shelf antennas make it possible to perform rapid initial system tests and proof of concepts experiments. This paper reports on the antenna performance of a cost effective commercial off the shelf printed Lop-periodic antenna supplied by Ettus Research. This antenna is specified to work in the UHF band with a bandwidth of 600 MHz (400 MHz to 1 GHz).**

Keywords—Antenna, log-periodic, performance modelling

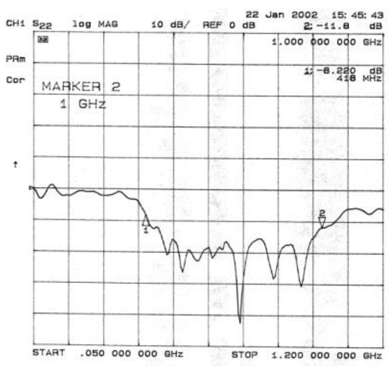
I. INTRODUCTION

Log-periodic antennas are useful for wide-band applications. There are a number of different designs and architectures. This paper will focus on a printed log-periodic antenna.

This paper reports on the antenna performance of a cost effective commercial off the shelf printed Lop-periodic antenna. This antenna works in the UHF band with a bandwidth of 600 MHz (400 MHz to 1 GHz) [1]. Fig. 1 provides a photo of this antenna, provided by Ettus, as well as the S11 information available [2]. The only other available information is on the frequency band and the gain, which is given as 5-6 dBi. No information was provided on the substrate.



(a)



(b)

Figure. 1 COTS printed Log-periodic (a) photo, (b) S11 graph

This antenna was acquired for initial radar system tests. This log-p antenna was reconstructed in the computational electromagnetic tool FEKO, and simulations were performed to obtain a better indication of the antenna pattern, and s-parameters. The system specifications required the antenna to operate with a frequency of 400 MHz to 1 GHz, have a wide beamwidth of 120°, and have a cross-coupling of less than -10 dB with an adjacent antenna, over the entire band.

II. BRIEF BACKGROUND ON LOG-PERIODICS

With a Log-P antenna, the active region, which is the portion of the antenna that is radiating or receiving radiation efficiently, shifts with frequency. The longest element is active at the lowest usable frequency, where it acts as a half wave dipole. As the frequency shifts higher, the active region shifts forward towards the shorter elements. The dielectric substrate has an effect on the wavelength, which can be calculated through equation (1) and (2). Equation (1) is used to cancluate the effective dielectric constant.

Effect of the material properties on the wavelength; the effective dielectric constant:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2} \times \frac{1}{\sqrt{1+\frac{10\times h}{w_s}}} \qquad (1)$$

where ε_r is the relative dielectric constant, h is half the thickness of the substrate (e.g. 1.6 mm/2), and w_s is the width of stripline. The effective wavelength can then be calculated using

$$\lambda = \frac{1}{\sqrt{\varepsilon_{eff}}} \times \frac{c}{f} \qquad (2)$$

III. SIMULATIONS OF GAIN

The antenna was initially reconstructed with rectangular striplines. The added details at the ends of the strips were then added. The latter design is shown in Fig. 2. The Gain was simulated over the frequency band and the results are provided in Fig. 3. On this graph a few results were compared, namely the gain of the antenna using a substrate with ε_r of 2.2 (red line), the antenna with only rectangular strips and no extra details (blue line), and the gain when the ε_r = 4.4 (green line). The yellow line is just a finer sampled version of the red line.

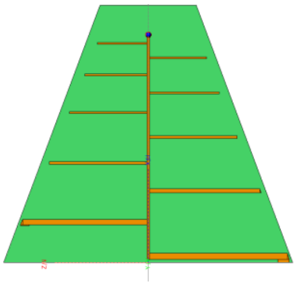


Figure 2: Reconstructed log-p antenna.

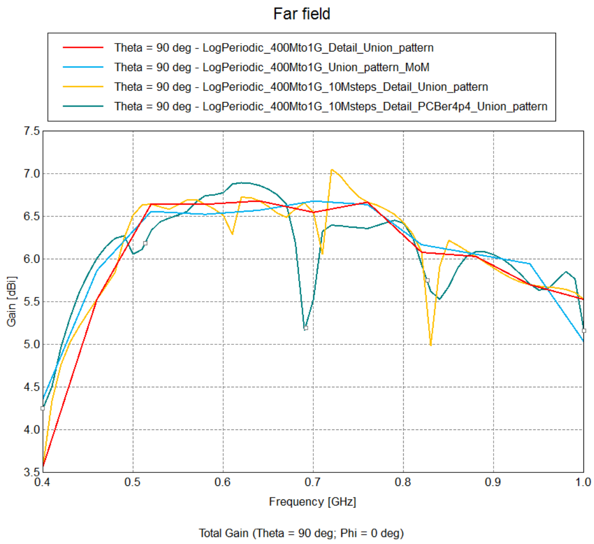


Figure 3: Gain of Log-p over the frequency band.

The gain of this antenna remains above 5 dBi over a frequency band of approximately 410 MHz to 1 GHz.

IV. Simulations of Cross Coupling

A number of simulations were performed to calculate the cross-coupling between two of these log-periodic antennas with various orientations.

A. HH

Fig. 4 shows the setup of two log-p antennas that are spaced at $\lambda/2$, at 430 MHz, both horizontally orientated (HH).

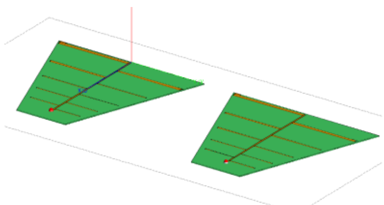
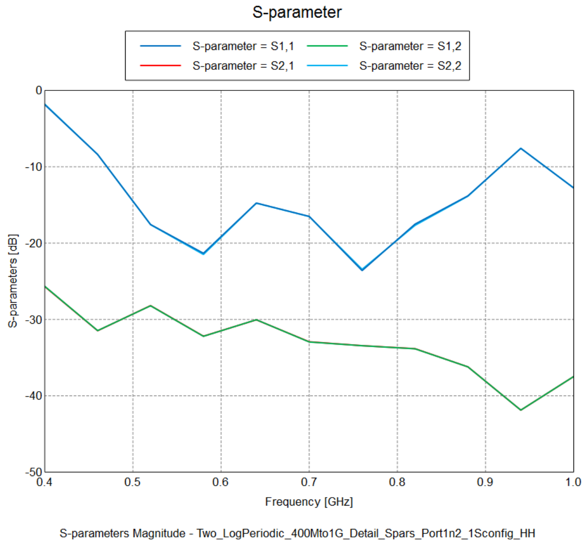
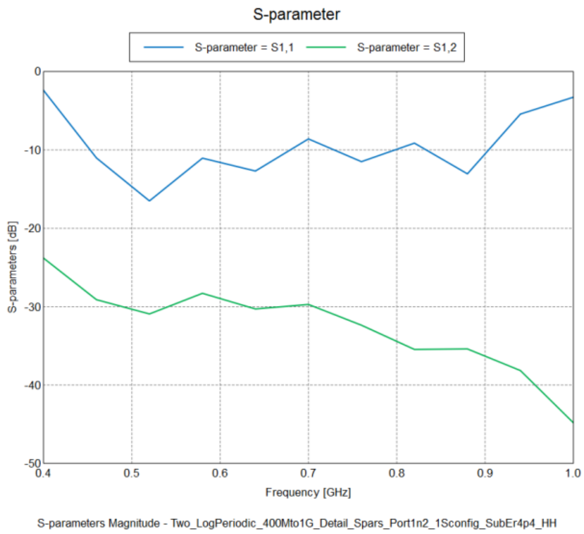


Figure 4: Two horizontal log-p antennas spaced at $\lambda/2$.

The simulations were performed for a substrate with a relative permittivity of 2.2 and 4.4. These results are provided in Figure 5.



(a)



(b)

Figure 5: S11 and S12 for Log-p antennas with a substrate of (a) relative permittivity = 2.2, and (b) 4.4.

The S11 and S22 remain below -10 dB (VSWR = 2) over most of the frequency range with both substrates. The cross coupling is also good, as it remains below -25 dB and -23 dB over entire frequency range for a substrate with er 2.2 and 4.4, respectively. Fig. 6 provides a cut through the far-field patterns at 400 MHz and 1 GHz.

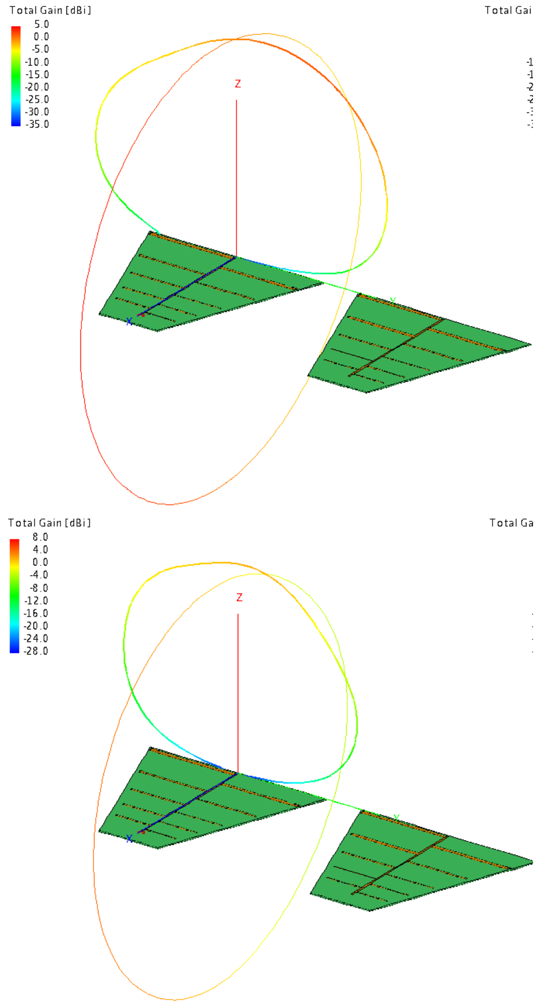


Figure 6: Cut through patterns at (a) 400 MHz and (b) 1 GHz.

B. VV

Fig. 7 shows the setup of two log-p antennas that are spaced at λ/2, at 430 MHz, both vertically orientated (VV). Fig. 8 provides the S11 and S12 results with a substrate of 4.4. A cut through the patterns are shown in Fig. 9.

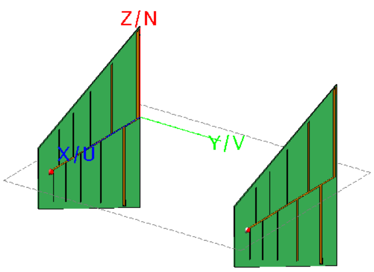


Figure 7: Two vertical log-p antennas spaced at λ/2.

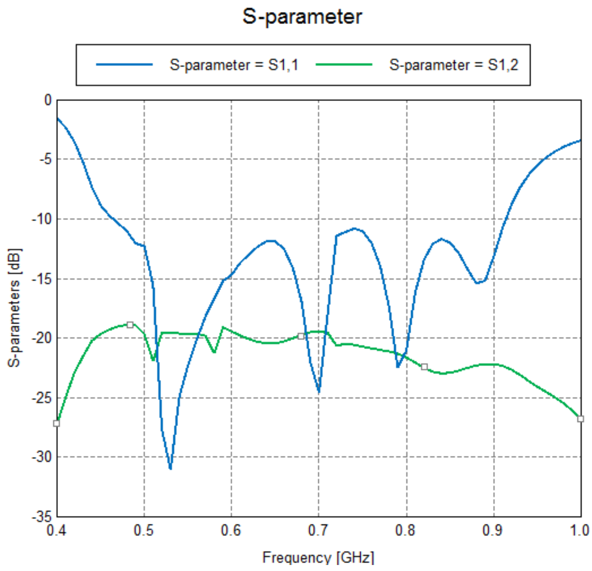
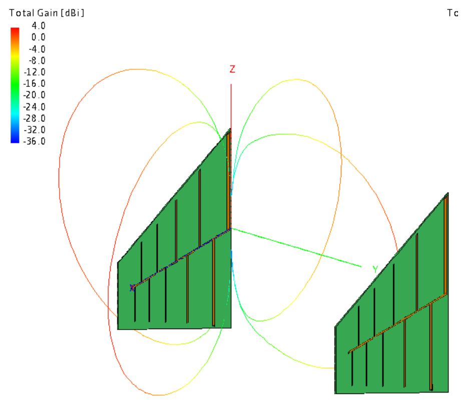
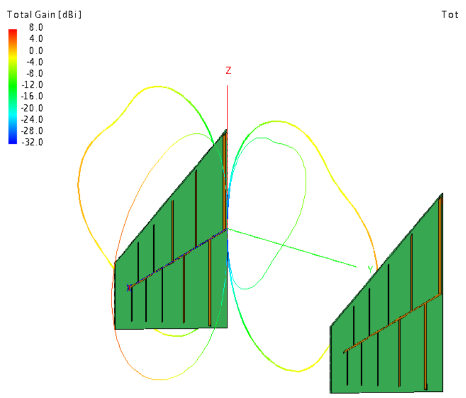


Figure 8: S11 of VV log-p setup with er = 4.4



(a)



(b)

Figure 9: Cut through patters at (a) 400 MHz and (b) 1 GHz.

The cross-coupling is slightly higher with this configuration, however it remains around -20 dB over the frequency range.

C. VH

Fig. 10 shows the setup of two log-p antennas that are spaced at λ/2, at 430 MHz, one horizontally orientated and the other one vertically (VH). Fig. 11 provides the S11 and S12 results with a substrate with er = 4.4, far-field cuts are shown in Fig. 12.

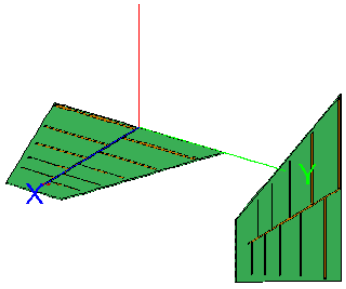


Figure 10: VH setup of log-p antennas spaced at λ/2.

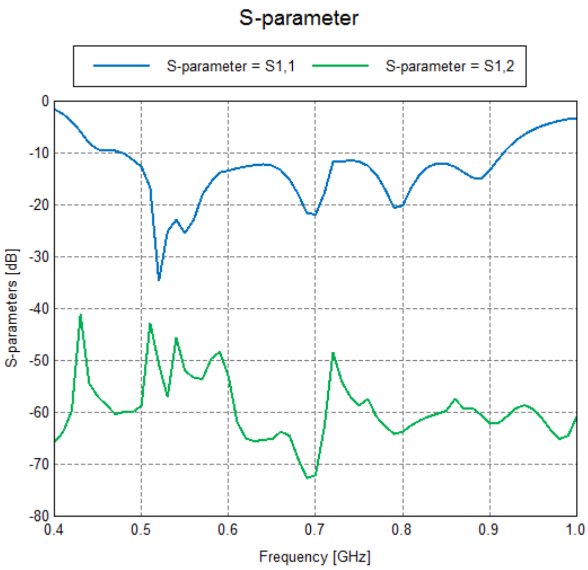
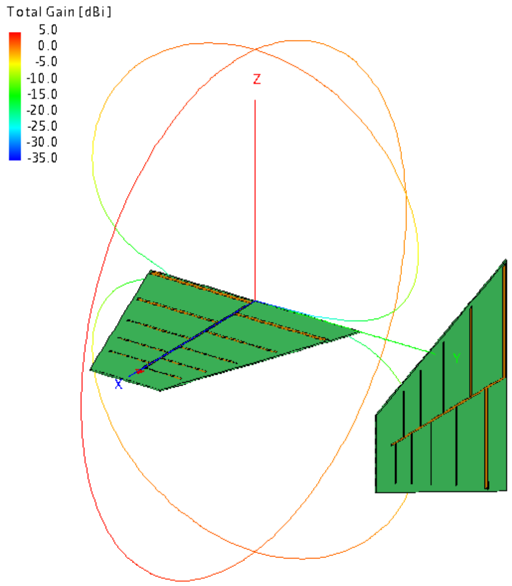
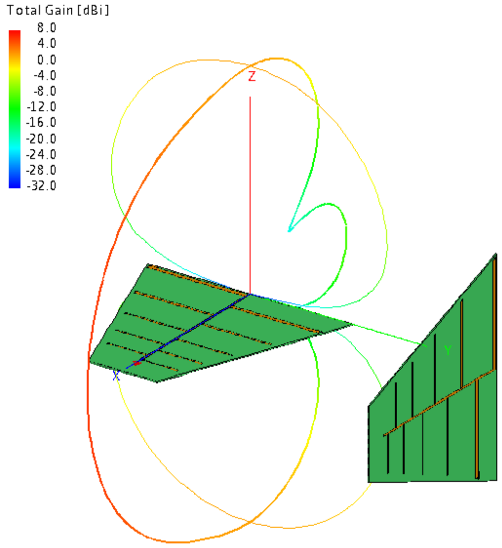


Figure 11: S11 of VH log-p setup with er = 4.4



(a)



(b)

Figure 12: Cut through patterns at (a) 400 MHz and (b) 1 GHz.

As expected, the cross coupling is very low with this configuration.

V. Conclusion

The performance of a cost-effective COTS UHF Log-periodic antenna, with very limited technical specifications / information available, was modelled. The gain was analysed with two different substrate materials, since the material was not specified for the antenna. The cross coupling was also investigated for three different configurations (HH, VV and HV). Future work will include measurements of the antenna in an anechoic chamber, as well as other investigations of interesting setups to potentially improve the gain. It is hoped that these results will help other users of these antennas to better understand their performance and the limitations of the antenna.

References

[1] Ettus Research, “LP0410 antenna,” 2019. [Online]. Available: https://www.ettus.com/all-products/lp0410/.

[2] Ettus Research, “LP0410,” 2019. [Online]. Available: https://kb.ettus.com/Antennas#LP0410