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Long-Wire Directive S-band Antenna

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***Abstract*—A resonant Long-Wire antenna for S-band is theoretically analyzed in terms of radiation pattern and impedance matching. A prototype of Long-Wire antenna was built, tuned and eventually tested in transmission mode, using an experimental setup developed for this purpose. As a tool for real environment characterization of this type of antenna, the amateur radio cross-band linear transponder onboard the geostationary artificial satellite Es'hail-2 (QO-100) is used.**

Keywords—Long-Wire antenna; S-band, Goubau Line; traveling wave antenna

I. INTRODUCTION

The Long-Wire (LW) antennas are still widely used by professionals as receiving antennas on the Medium and Short-Wave bands, as well as transmitting antennas on these frequency bands for portable and emergency radio stations. They are also extensively used by the community of radio amateurs, for temporary and permanent installations [1].

The Long-Wire antennas described in the literature are divided in two categories: resonant and non-resonant antennas [2].

The non-resonant LW antennas are also known as traveling wave antennas or aperiodic antennas. They are load terminated and have a unidirectional radiation pattern.

The resonant LW antennas, are also named standing wave or periodic or tuned antennas, and have a bidirectional radiation pattern. They have a radiator length greater than one wavelength of the radio waves (multiples of half wavelength $n*\lambda/2$, $n > 2$) [2].

Less interest was shown on the use of these antennas for higher frequencies, VHF and up [3], [4], due to some drawbacks such as the presence of side and back lobes, and an unusual radiation pattern.

A resonant LW antenna for the S-band (2-4 GHz) is proposed as an experimental test bed and as a practical KISS satellite communications antenna for portable/emergency operation.

Worth mentioning in the context the Goubau one-wire transmission line that exhibits very low loss at high frequencies compared to the widely used coaxial transmission lines. The impedance transitions (launcher and receiver) of the Goubau line are of interest for the impedance matching of the analyzed Long-Wire antenna [5].

For Over-the-Air (OTA) tests of the LW antenna, the use of the geostationary artificial satellite Es'hail-2 is proposed. The onboard narrowband linear transponder has the uplink in the S-band (2.4 GHz) and the downlink in the X-band (10 GHz) [6].

II. ANTENNA GEOMETRY

The analyzed resonant LW antenna, designed for 2.4 GHz band, consists in a single radiator element, for convenience having a length of 33 quarter-wavelengths at the frequency of operation, or about one meter is size. The impedance matching unit consists in two radial elements, a quarter-wavelength in size (3.6 cm) (Fig. 1).

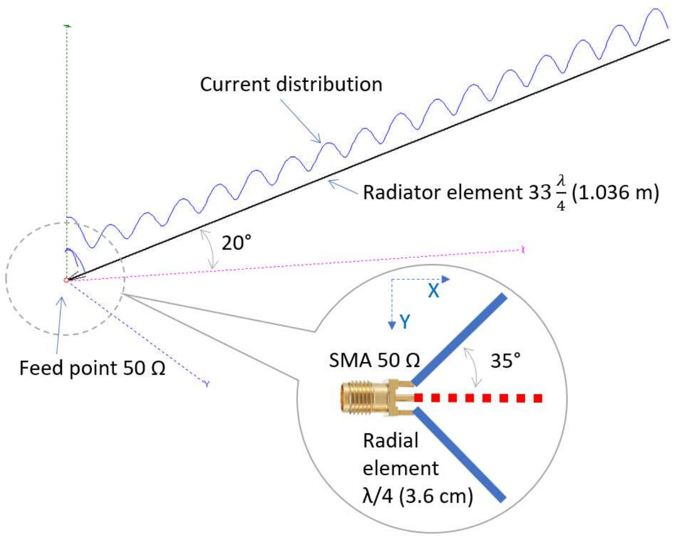

Fig. 1. Long-Wire antenna geometry and current distribution.

The radial elements are placed symmetrically with respect to the radiator element and tilted forward such that an impedance of 50 ohms is achieved.

III. SIMULATION RESULTS

Simulations of the proposed LW antenna were made using the antenna analyzer software MMANA-GAL [7]. The chosen material for the elements was copper wire 3 mm in diameter, and medium ground properties were considered (dielectric permittivity ε=13, conductivity σ=5 mS/m).

The antenna radiator element was tilted in order that the main radiation lobe fit the elevation of the Es'hail-2 satellite, as seen from the test site (geographical position). The height above the ground of the feed point that was chosen in the simulation was of 2 cm.

In Fig. 2 the simulated total far field radiation pattern in the vertical plane is shown. The maximum theoretical gain of Ga=10.4 dBi is obtained at 36° elevation angle.

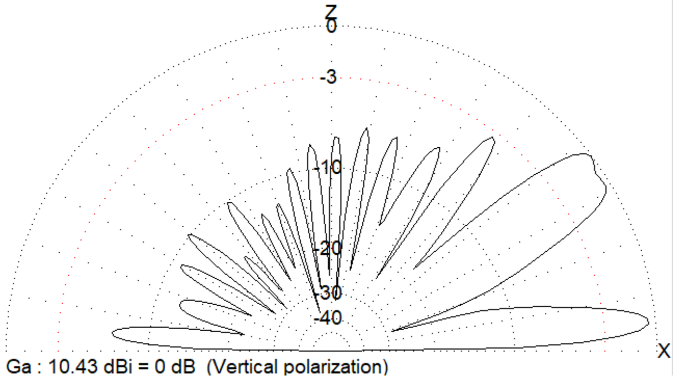

Fig. 2. Total far field radiation pattern of the LW antenna in the vertical plane.

The total simulated radiation pattern in the horizontal plane is shown in Fig. 3. The front to back radio is F/B=6.7 dB as measured at 120° azimuth and 60° elevation.

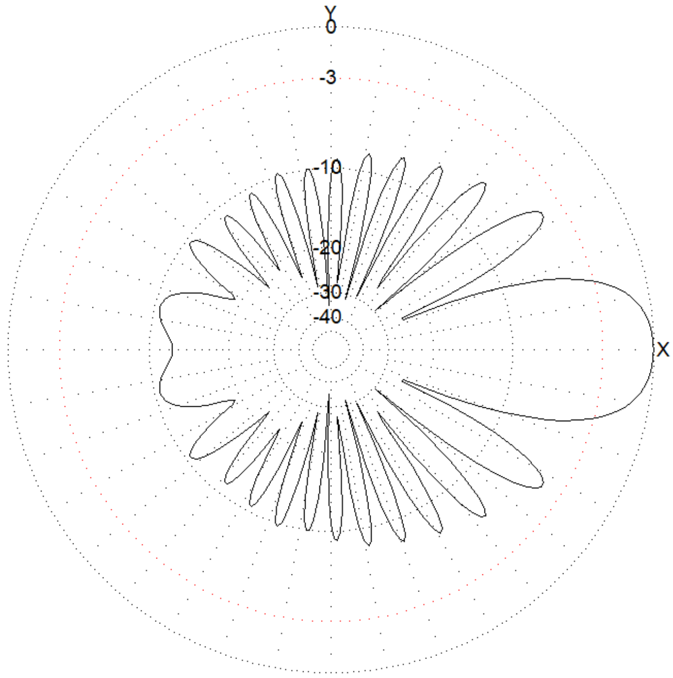

Fig. 3. Total far field radiation pattern of the LW antenna in the horizontal plane.

The 3D far field plot reveals a cone shaped main lobe, exhibiting a deep null along the antenna radiating element (Fig. 4).

For the chosen ratio radiator length/wavelength, the maximum gain is obtained at an offset angle of about 17 degrees from the radiator element.

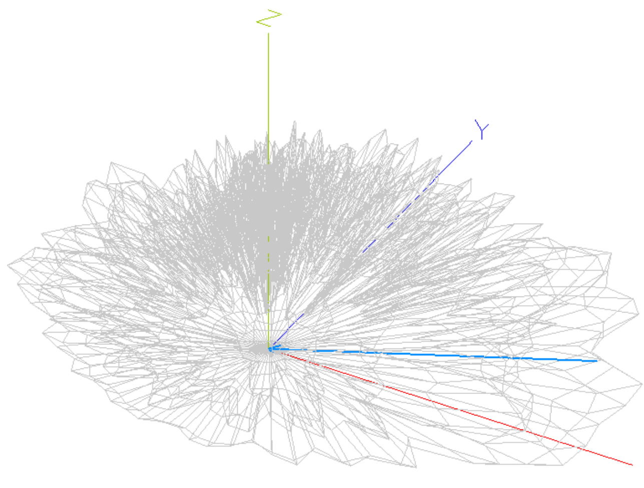

Fig. 4. 3D total far field radiation pattern of the LW antenna.

The theoretical standing wave ratio (SWR) characteristic across a 40 MHz frequency band is shown in Fig. 5. At resonance, after optimization, a SWR=1.03:1 was obtained. The bandwidth for SWR=1.5:1 is about BW=28 MHz.

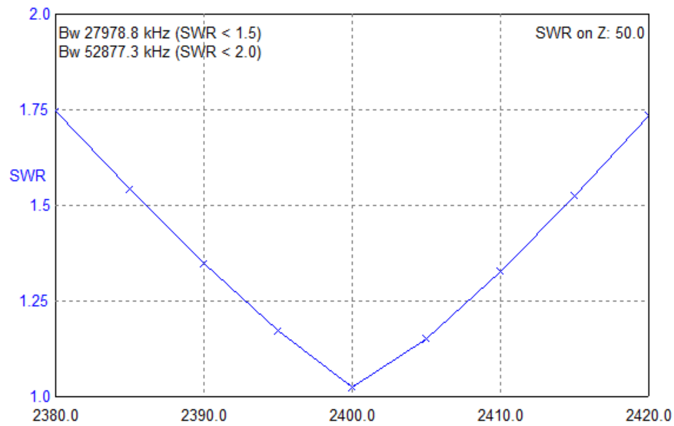

Fig. 5. The simulated SWR for the LW antenna.

The variation of the resistive R and reactive X components of the impedance, obtained by simulation in the same 40 MHz frequency band is shown in Fig. 6.

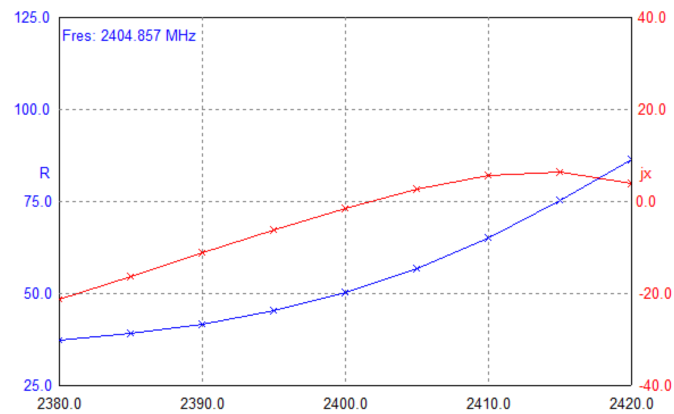

Fig. 6. The impedance Z=R+jX components of the LW antenna.

In Fig. 7 are represented the simulated front to back ratio FB and antenna gain GA.

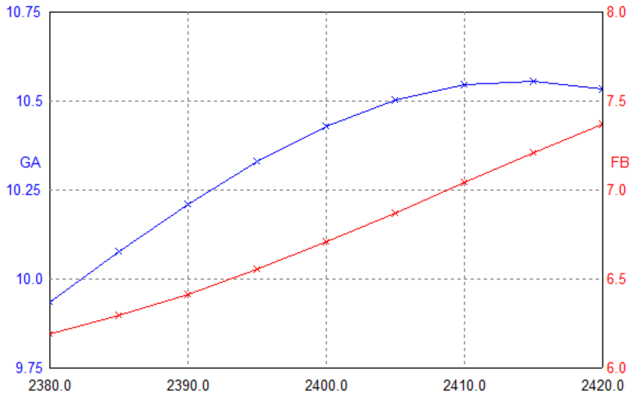

Fig. 7. Simulated antenna gain GA and front to back ratio FB for the LW antenna.

A test 2.4 GHz LW antenna was built according to the simulation parameters and results (Fig. 8).

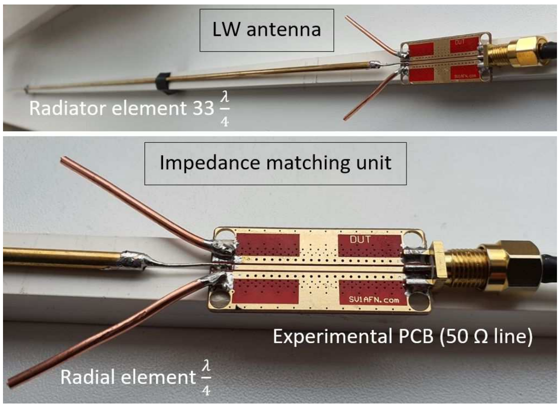

Fig. 8. The LW antenna prototype (perspective view – upper image, detail of the impedance matching unit – lower image).

The Agilent N9330B Antenna and Cable Tester was used for SWR measurements (Fig. 9).

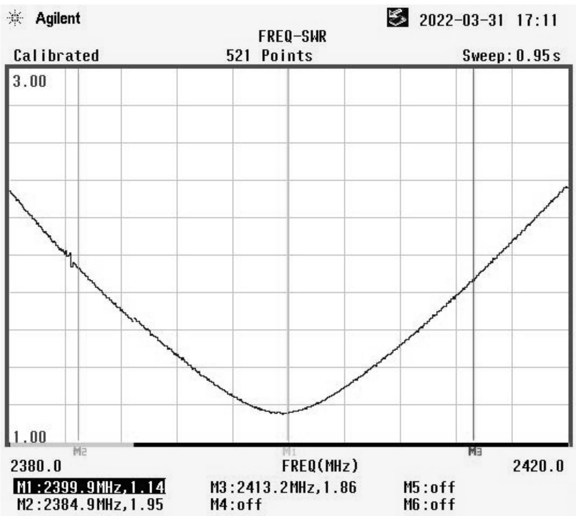

Fig. 9. Long-Wire antenna SWR measurement.

For Over-the-Air (OTA) tests of the LW antenna, the geostationary artificial satellite Es'hail-2 was used. The onboard narrowband linear transponder (Quatar OSCAR-100 – the first geostationary amateur radio transponder) has the uplink in the S-band (2.4 Ghz) and the downlink in the X-band (10 GHz) [6].

The antenna under test (AUT LW) is operated in transmission mode. For radio downlink feedback, online radio receivers are used: the QO-100 WebSDR [8], hosted at Goonhilly Earth Station in Cornwall, UK and the OpenWebRX receiver [9] at the Astronomical Observatory of Stefan cel Mare University in Suceava, Romania (USV). For the USV test site the QO-100 satellite is placed at almost 180° azimuth and 35.3° in elevation. The geometry of the radio path is shown in Fig. 10.

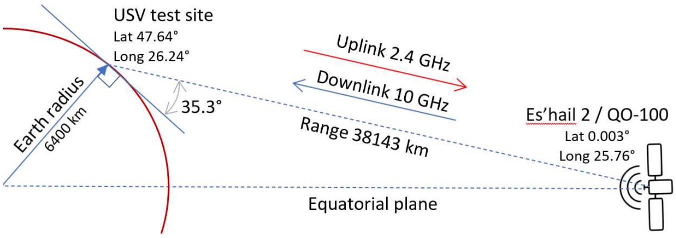

Fig. 10. The radio path geometry for QO-100 satellite OTA test.

The experimental 2.4 GHz transmission setup comprise the Agilent N5183A signal generator that can deliver a CW (continuous wave) signal, at 10 dBm maximum output power.

In order to overcome the uplink path losses (free space loss, coaxial cable attenuation, transponder noise figure) a higher power is required for a positive link budget. An RF amplifier chain was set-up using the components described in Fig. 11.

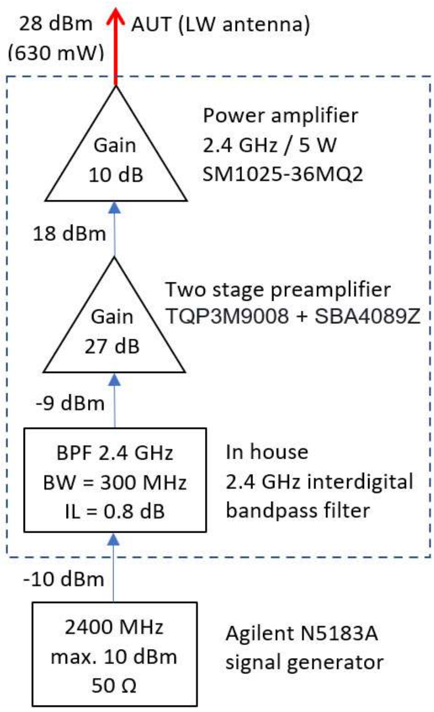

Fig. 11. Experimental 2.4 GHz transmission setup block diagram.

In Fig. 12 the layout of the RF amplifier chain is shown.

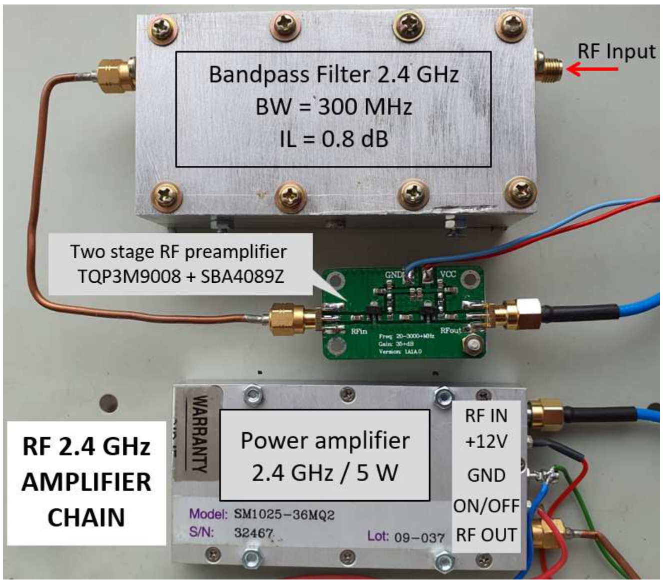

Fig. 12. RF amplifier chain setup.

A total estimated power of 28 dBm was obtained, limited only by the 1 dB compression point (P_{1dB}) of the preamplifier.

For reaching the full power of 37 dBm (5 W) that can be delivered by the power amplifier, a 27 dBm (0.5 W) preamplifier is necessary.

The relative signal strength was measured with the WebSDR integrated power meter, in a bandwidth of 200 Hz.

For the antenna under test LW, the measurements showed a signal to noise ratio of around SNR=6 dB, enough to detect the presence of the signal in the WebSDR receiver waterfall (Fig. 13).

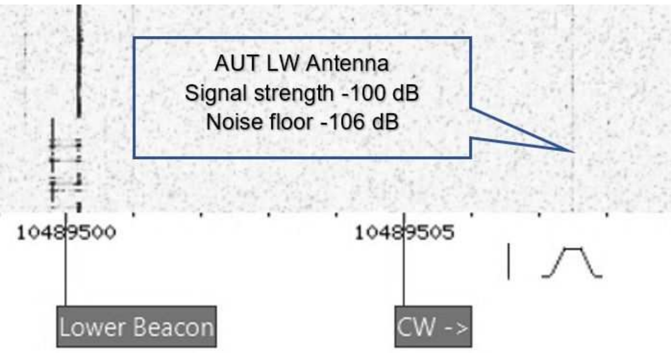

Fig. 13. WebSDR spectrogram for the LW antenna - relative signal strength measurement.

The LW antenna was compared against a commercial 2.4 GHz California Amplifier Parabolic Grid antenna, CALAMP-PG24, having an advertised gain of 24 dBi.

The signal to noise ratio was in this case 10 dB better, as expected (Fig. 14).

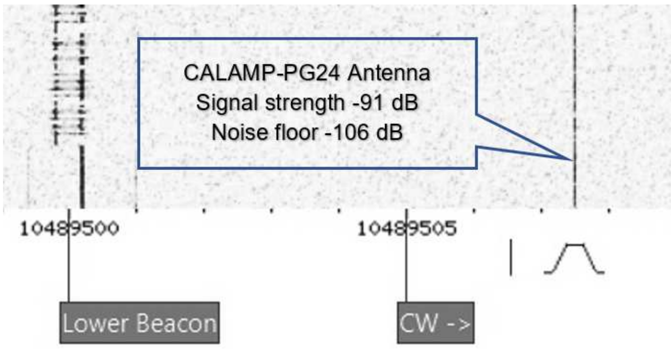

Fig. 14. WebSDR spectrogram for the CALAMP-PG24 antenna - relative signal strenght measurement.

The OTA tests were made according to the legislation of ITU (International Telecommunication Union) regarding the rules and regulations for amateur radio communications.

This preliminary test showed the fact the proposed resonant LW antenna behaves according to the expectations.

IV. CONCLUSIONS

Long-Wire antennas are the simplest construction antenna structures that can provide directivity (gain) features. Phased arrays of such antennas are of interest for very high frequencies, going up to millimetric wavelengths.

A single element resonant Long-Wire antenna was investigated, operating in 2.4 GHz band, the OTA test showing the fact the proposed antenna meets the expectations.

Future works are oriented to a precise characterization of the radiation pattern for the prototype antenna, that requires mainly a precise aiming to the satellite. Anechoic chamber measurements are also in view.

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