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Triband Antenna Feeding Circuit for Circular Polarization Diversity

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Abstract— **In this paper, a compact and original feeding circuit architecture is proposed to synthesis the circular polarization of a triband antenna. A diplexer is used in this circuit in order to achieve circular polarization diversity, that is, right-hand circular polarization (RH-CP) for two radio-navigation bands (GPS/Galileo) and left-hand circular polarization (LH-CP) for a telemetry band (MicroSat TM). Simulation and measurement results are presented and validate the proposed feeding circuit concept.**

I. INTRODUCTION

The need for circularly polarized multiband antennas is increasing particularly with the multiplication of satellite radionavigation systems (GPS, Galileo, GLONASS,...). Recently, an original circularly polarized triband antenna covering two radionavigation bands (GPS/Galileo: 1.197 and 1.575GHz) and one telemetry band (TM MicroSat : 2.245GHz) has been published by the authors [1]. The circular polarization behaviour of this antenna is obtained by feeding its four radiating elements with progressive 90°-phase difference and equal magnitude (circular polarization synthesis). The use of such a technique is motivated by its good performance in terms of purity of circular polarization. A feeding circuit is therefore needed in order to provide the required excitation law at the different operating frequency bands of the antenna. To our knowledge, compact feeding circuits dealing with more than two frequency bands are rare, not to say, nonexistent. Moreover, the need for different circular polarizations (right or left) for different bands will further complicate this circuit.

In this paper, an original multiband feeding circuit architecture is proposed for circular polarization diversity. As an application, a very compact triband feeding circuit (11cm x 6.5cm) is designed, fabricated and measured. It provides right hand circular polarization (RH-CP) for two radionavigation bands and left hand circular polarization (LH-CP) for one telemetry band. For the first time, the simulation and measurement results of this circuit are presented and discussed.

II. DESCRIPTION OF THE MULTIBAND FEEDING ARCHETECTURE FOR POLARIZATION DIVERSITY

The proposed multiband feeding circuit architecture for circular polarization diversity is depicted in Figure 1. In this architecture, the bands needing right hand circular polarization (RH-CP) and those requiring left hand circular polarization (CP-LH) are separated, processed separately and then recombined using diplexers. Generating the required phase excitation law (progressive 90 °-phase differences) is achieved by a standard architecture based on 90°/180° couplers. The design of the diplexers of the Figure 1 remains the most difficult part. A diplexer based on distributed elements was designed for a multiband antenna with different polarization (linear and RH-CP) [2]. However, the use of distributed elements leads to a drastic increase of size compared to a lumped element implementation.

III. APPLICATION: GPS/GALILEO/TM MICROSAT TRIBAND ANTENNA FEEDING CIRCUIT

A. Description of the application

The considered application deals with the feeding of a triband antenna covering two radionavigation bands (Galileo/ GPS) and a telemetry band (TM MicroSat) [1]. Circular polarization diversity is required in order to set right hand circular polarization for navigation applications and left hand circular polarization for telemetry applications. The technical specifications for this application are listed in Table I.

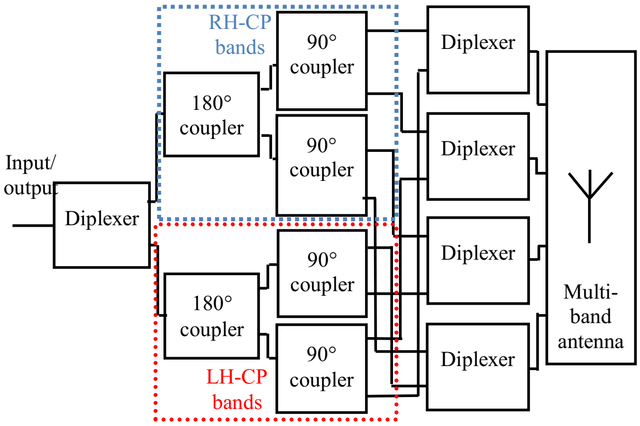


Figure 1. Feeding circuit architecture for circular polarization diversity

TABLE I
TECHNICAL REQUIREMENTS FOR THE GPS/GALILEO/MICROSAT TRIBAND ANTENNA

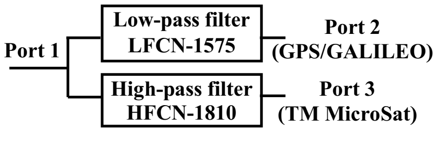
	Band 1	Band 2	Band 3
Bands	E5a/L5 and E5b	Extended L1	Telemetry (TM)
Systems	GPS/Galileo	GPS/Galileo	CNES MicroSat
Center frequency	f_1=1.197 GHz	f_2=1.575 GHz	f_3=2.245 GHz
Bandwidth	50 MHz	32 MHz	90 MHz
Polarization	Right-hand CP		Left-hand CP

B. Couplers selection

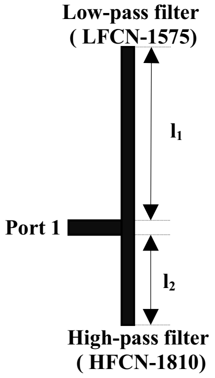
The couplers for the two GPS/Galileo bands (RH-CP sub-circuit in Figure 1) should cover a relative bandwidth of about 33%. They are connected in such a way to generate a right hand circular polarization in the bands GPS/Galileo. On the other hand, the couplers for MicroSat TM band (LH-CP sub-circuit in Figure 1) would be relatively narrowband since the relative bandwidth of the telemetry band is about 4%. However, they should be connected so as to obtain a left hand circular polarization. In order that the feeding circuit may be easily integrated into the limited area available in the triband antenna [1], all the used couplers should be very compact. One can find a variety of commercial compact wideband surface-mount couplers with relative bandwidth up to 140%. For their compactness, these commercial couplers have been chosen for the design of the feeding circuit. However, due to the lack of commercial 180° couplers covering the bands of interest, each 180° coupler is replaced by three 90° couplers at the price of 3dB of additional losses. The 90° couplers chosen for GPS/Galileo bands and TM MicroSat band are, respectively, *Mini-Circuits QCN-19* and *QBA-24W* [3]. These components are not only compact but also exhibit good performance in the bands of interest. Furthermore, the S-parameters of these couplers can be directly downloaded from the manufacturer's website.

C. Diplexer design

The diplexer should occupy a small area and present low insertion loss and high levels of channel isolation. It can be realized according to two techniques [4]: the use of directional couplers or the connection of two parallel filters. The first option leads to a not easily compactable architecture, thus the second technique has been chosen. The designed diplexer is formed by the connection of a low-pass filter allowing the passage of the two GPS/Galileo bands and a high-pass filter allowing through the MicroSat TM band (see Figure 2 (a)). For compactness reasons and since five diplexers are required in the feeding circuit, the design of these two filters using distributed elements would not be possible. Thus, commercial surface-mount filters are selected for the design of the diplexer. This latter is designed using *Mini-Circuits LFCN-1575* (low-pass filter) and *HFCN-1810* (high-pass filter)[3].



(a)



(b)

Figure 2. (a) The diplexer configuration; (b) The optimized T junction

Ideally, a filter should present zero impedance in its pass band and infinite impedance at all other frequencies. The design of a diplexer by the connection of two filters requires the use of filters having infinite impedance in their stop bands. If this condition is not satisfied, each filter may degrade the other performance. Using the S-parameters provided by *Mini-Circuits*, it was found that the two selected filters have relatively low input impedance in their rejection band. Consequently, the diplexer can not be simply designed by the straightforward connection of these two filters. One solution is to add impedance transformers or simply transmission lines upstream of the two filters in order to increase their input impedance at the reject band. These impedance transformers should not much affect the input impedance in the pass band. Using microstrip technology, the low-pass filter (LFCN-1575) is preceded by a microstrip line of length l_1 which transforms its low input impedance in the MicroSat TM band to a relatively high value. Similarly, the high-pass filter (HFCN-1810) is loaded by a microstrip line with length l_2 in order to increase the filter's input impedance in the GPS/Galileo bands. The T-junction thus constructed is illustrated in Figure 2 (b). To get the best performance in terms of insertion loss and rejection at the three operating bands of the antenna, an optimization of the lengths l_1 and l_2 (see Figure 2 (b)) is performed using *Agilent ADS*. The substrate used is *TACONIC CER 10-0250*, which has a relative permittivity constant of 9.5, with 0.635 mm thickness, and a loss tangent (tanδ) of 0.0035. A 50Ω microstrip line on this substrate is approximately 0.6mm in width. The above-mentioned optimization yields the optimal values for the lengths l_1 and l_2 as follows: l_1=22.9mm and l_2=15.1mm. Figure 3 plots the insertion loss and the channel isolation of the diplexer formed by the combination of the two filters (LFCN-1575 and HFCN-1810) and the optimized T-junction shown in Figure 2 (b).

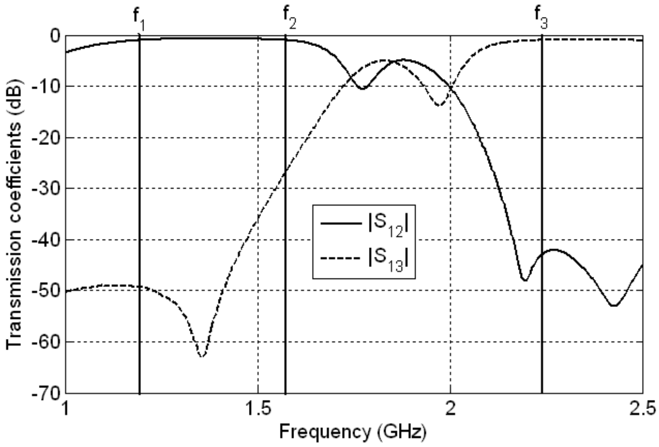


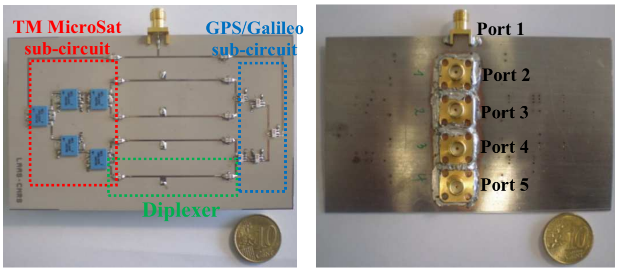
Figure 3. Simulated transmission coefficients of the optimized diplexer

D. *Feeding circuit simulation and realization*

The simulation of different parts of the feeding circuit is achieved using *Agilent ADS*. The couplers and the filters are modeled by their S-parameters which are provided by the manufacturer (*Mini-Circuit*). It should be noted that the circuit-based simulation does not take into account parasitic effects related to the interconnection lines and connectors. Figure 4 shows photographs of the fabricated compact feeding circuit (110mm x 65 mm). 50Ω chip resistors (EIA case size 0402) were used to load the isolated and unused outputs of the different couplers (*QCN-19*, *QBA-24W*).

E. *Measurement results and discussion*

Measurements of the feeding circuit were performed using *Wiltron 360B* VNA. Two ports were measured simultaneously while the three others were loaded with 50Ω SMA terminations. Figure 5 shows the simulated and measured transmission coefficients of the fabricated feeding circuit. The phase differences between transmission coefficients (measured only) of the fabricated feeding circuit are depicted in Figure 6. Table II summarizes the simulated and measured phase differences between transmission coefficients at the three operating frequencies of the antenna.



(a) Top view (b) Bottom view

Figure 4. Photographs of the fabricated compact feeding circuit for circular polarization diversity

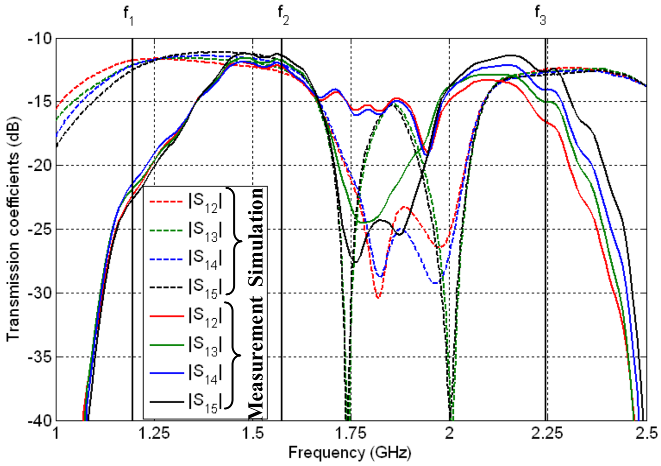
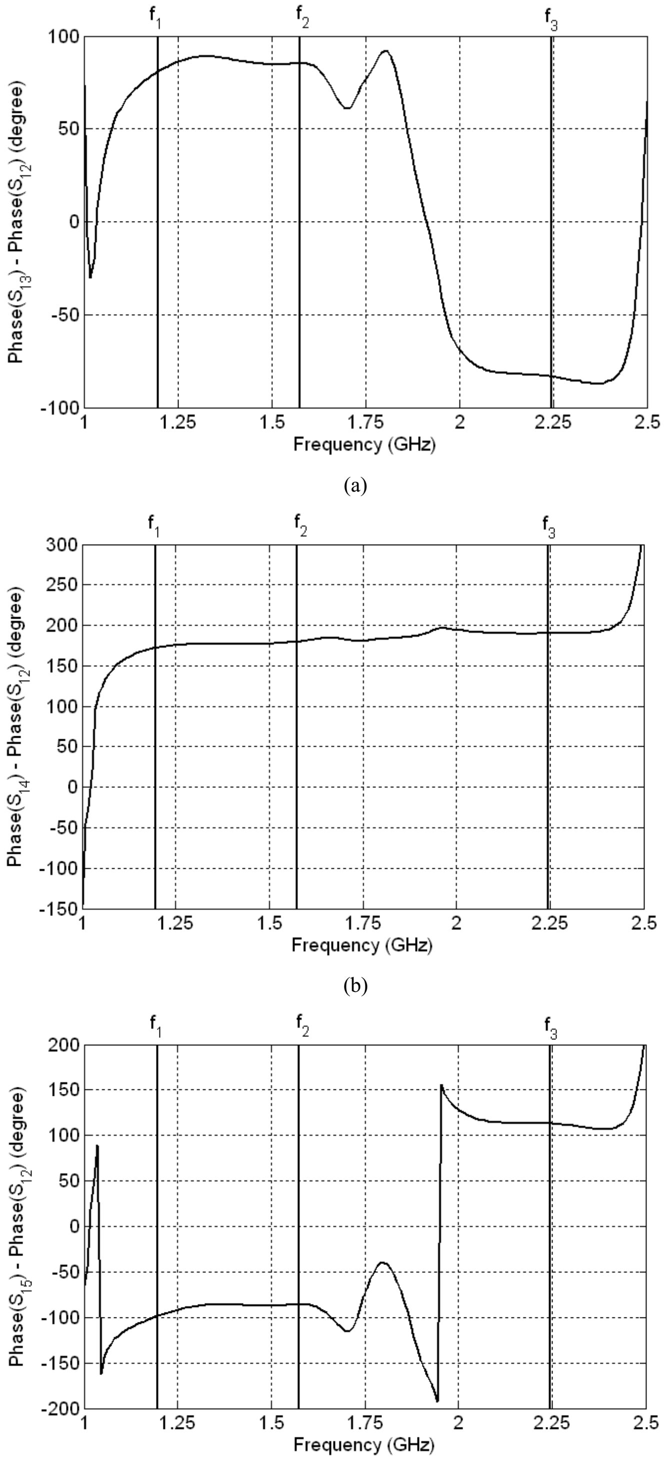


Figure 5. Simulated and measured transmission coefficients of the fabricated feeding circuit

At the intermediate frequency (1.575 GHz), simulated results of the amplitudes of the transmission coefficients show a good agreement with the experimental results. As a matter of fact, an amplitude difference between the four transmission coefficients not greater than 1 dB is obtained at this frequency. At the upper frequency (2.245 GHz), an amplitude imbalance of nearly 4 dB is observed experimentally (only 0.43 dB was expected from simulation). However, the amplitude attenuation of the four transmission coefficients at this frequency is lower than that obtained at the lower frequency (1.197 GHz). At this frequency and despite the low amplitude imbalance (1.5dB), the amplitudes of the transmission coefficients differ significantly from those predicted by simulation (about -21dB in measurement compared to -12dB in simulation). The phase difference results indicate that the maximum phase deviation does not exceed 10 ° between the four outputs of the feeding circuit at the two first frequencies (lower and intermediate). However, at the upper frequency, a deviation of about 23 ° is obtained in the worst case.

Additional simulations and measurements were conducted to understand the origin of this discrepancy between measurement and simulation, especially noted at the lower frequency. It has been found that this unexpected difference comes from the designed diplexer based on commercial filters. In fact, the design of the diplexer using the measured S-parameters instead of those given by the manufacturer would be more appropriate. Our approach (in progress) is now to redesign and optimize the diplexer's T-junction by using our measured S-parameters and, hence, to reduce the significant difference mainly observed at the lower frequency of the feeding circuit. Due to its only two parameters l_1 and l_2, the simple structure of the T- junction would not be difficult to optimize by using the new measured filter S-parameters. The experimental results of the improved feeding circuit design will be presented in the conference.



(a)

(b)

(c)

Figure 6. Measured phase differences between transmission coefficients: (a) $\angle S_{13}$-$\angle S_{12}$; (b) $\angle S_{14}$-$\angle S_{12}$; and (c) $\angle S_{15}$-$\angle S_{12}$.

TABLE II
SIMULATED AND MEASURED PHASE DIFFERENCES BETWEEN TRANSMISSION COEFFICIENTS AT THE THREE OPERATING FREQUENCIES OF THE TRIBAND ANTENNA

		$\angle S_{13}$-$\angle S_{12}$(°)	$\angle S_{14}$-$\angle S_{12}$(°)	$\angle S_{15}$-$\angle S_{12}$(°)
f_1=1.197 GHz	Simulation	90.1	179.2	-90.6
	Measurement	80.8	172.1	-98.4
f_2=1.575 GHz	Simulation	90	180.2	-89.8
	Measurement	85.1	179.6	-86
f_3=2.245 GHz	Simulation	-90.1	179.6	89.5
	Measurement	-83.1	190	113.1

IV. CONCLUSION

In this paper, a new compact feeding circuit was proposed for a triband antenna with circular polarization diversity. The two radionavigation bands of this antenna require a right hand circular polarization while the telemetry band requires a left hand one. Even if a new design of the diplexer using the measured S-parameters of its filters is necessary to: (1) reduce the insertion losses at the lower and upper frequency bands and (2) improve the phase deviation performance at the upper frequency band, the obtained results confirm the feasibility and also the difficulty of designing a compact feeding circuit for triband antennas with circular polarization diversity.

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