Experimental Studies of Broadband Transmission Line Transformers

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Abstract – **In this paper are given experimental results obtained from studies of broadband transmission line transformers in the frequency response of their used ferrite toroidal cores 0,5÷30 MHz with coefficients of resistant ratio 1:1, 4:1 and 1:4. Some transformers are practically implemented with 3 and 5 twists per 1 cm of pair copper enamelled wires with ferrite toroidal cores manufactured by the firm Amidon FT82-77 and FT114-77. The obtained results – characteristics and qualitative parameters are generalized and presented in graphical and tabular form.**

Keywords – **Experimental studies, Broadband transmission line transformers, Qualitative parameters, 3 and 5 twists per 1 cm.**

I. Introduction

Broadband co-ordination and transformation of input and output resistance of a high-frequency amplifier, between two adjacent amplifier stages as well as broadband power aggregation and division can be carried out by transmission line transformers employing an electromagnetic connection between the primary and secondary windings. To provide the necessary transformation coefficient of resistances and minimum deco-ordination is an important prerequisite for achieving a wide operating frequency band. These transformers have high efficiency and reliability and through them can be made: galvanic dissociation between nodes and units of the equipment, transition from asymmetric to symmetric I/O and vice versa, they have small sizes, etc.

II. Implementation and Experimantal Studies of Broadband Transmission Line Transformers

A. Implementation of broadband transmission line transformers

Broadband Transmission Line Transformers (BTLT) are constructed employing appropriately interconnected transmission lines, positioned on a ferromagnetic core which is mostly of toroidal shape [3]. The input signal excites electromagnetic waves whose linear combinations depending on the type of line connection, determine the output signal voltage. Since the resistance transformation of BTLT is associated with changes in the coefficient of voltage transmission A_U ($nz=n_U^2$) when nz=4:1, n_U=2:1 and A_U=0,5. For nz=1:4, n_U=1:2 and A_U=2. The operating principle of broadband transmission line transformers is illustrated in Fig. 1.

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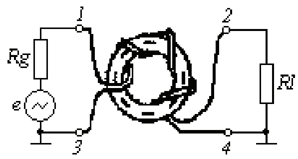

Fig. 1. Transmission Line Transformer

The main component in transmission line transformers is the ferrite toroidal core used. Some of the most important catalog parameters of ferrite toroidal cores manufactured by the firm Amidon FT82-77 and FT114-77 are presented in Table 1 [1].

TABLE I
CATALOG PARAMETERS OF AMIDON FERRITE TOROIDAL CORES FT82-77 AND FT114-77

Parameter	Ferrite core grade, Amidon	
	FT82-77	FT114-77
D_{dim}, mm	21,000	29,000
d_{dim}, mm	13,100	19,000
h_{dim}, mm	6,350	7,000
l_e, cm	5,260	7,420
A_e, cm^2	0,246	0,375
V_e, cm^3	1,290	2,790
Δf, MHz	0,5÷30	0,5÷30
A_l, mH/1000w	1170	1270
μ_r	2000	2000
ρ, Ω.cm	1.10^2	1.10^2

The transmission lines implemented with pair copper enamelled wires were most widely used in the frequency range 0,1÷50 MHz and to ensure the characteristic impedances from 15÷20 to 100÷150 Ω using BTLT [3]. Analytical determination of the geometry of these lines for necessary characteristic impedance Z_0 is too complicated therefore it is appropriate the construction parameters to be selected experimentally. It is recommended that the wires should be wound with a large number of twists per unit of length, not to change the characteristic impedance along the line [6].

The connection method and the values of input and output resistance of the co-ordinating (nz=1:1) and transforming (nz=4:1 and nz=1:4) the resistance broadband transmission line transformers are shown in Fig. 2.

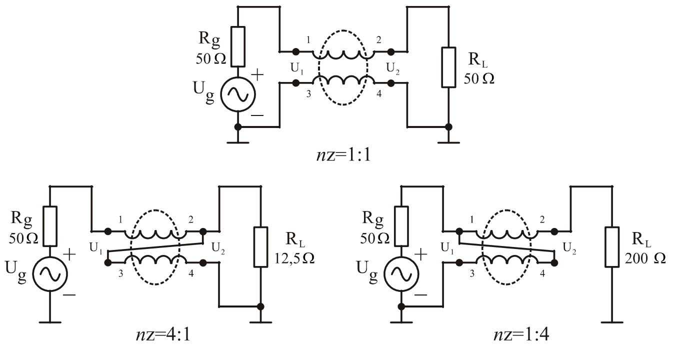

Fig. 2. Connection of BTLT with *nz*=1:1, *nz*=4:1 and *nz*=1:4

Broadband transmission line transformers with ferrite toroidal cores by the firm Amidon FT82-77 and FT114-77 with 7 windings of twisted pair copper enamelled wires with diameter *d*=0,62 mm when the number of twists is equal to 3 and 5 per 1 cm are implemented practically. The same design implementation of the broadband transmission line transformers with a small and large ferrite core is used, and the corresponding coefficient of transformation is provided with the necessary transmission lines connection to the source and load, and their corresponding values (Fig. 2). The experimental studies were carried out with values of the input voltage U_1=48,76 mV and U_1=21,2 mV.

B. Experimental results of BTLT with toroidal ferrite core Amidon FT82-77 with nz=1:1, nz=4:1 and nz=1:4

In Fig. 3 and Fig. 4 are presented the obtained amplitude-frequency responses (AFR) in graphic form for BTLT with ferrite core Amidon FT82-77 with 3 twists per 1 cm respectively when U_1=48,76 mV and U_1=21,2 mV.

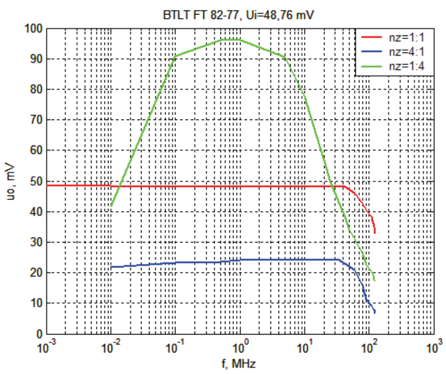

Fig. 3. AFR of BTLT with ferrite core FT82-77, with 3 twists per 1 cm when U_1=48,76 mV

Based on the results presented in Fig. 3 and Fig. 4 it is established that:

- when the coefficient of resistance transformation is *nz*=1:4, a drop of amplitude-frequency response at low and high frequencies is observed, from where there is a clearly formed frequency band of transmission;
- the amplitude-frequency response slopes at high frequencies are steeper when reducing the value of input voltage; there are sections with a different drop in individual frequency bands; in this case the frequency band is wider.

Conclusion: The transmitted frequency band expands when the value of input voltage is reduced.

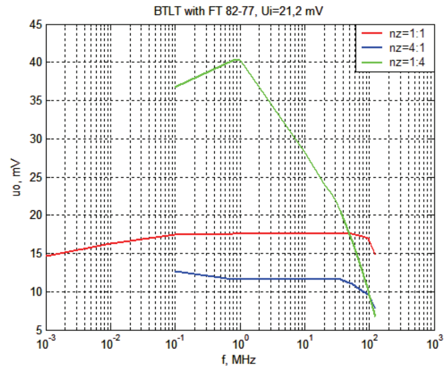

Fig. 4. AFR of BTLT with ferrite core FT82-77, with 3 twists per 1 cm when U_1=21,2 Mv

In Fig. 5 and Fig. 6 are presented graphically AFR of BTLT with ferrite core Amidon FT82-77, respectively when U_1=48,76 mV and U_1=21,2 mV with 5 twists per 1 cm.

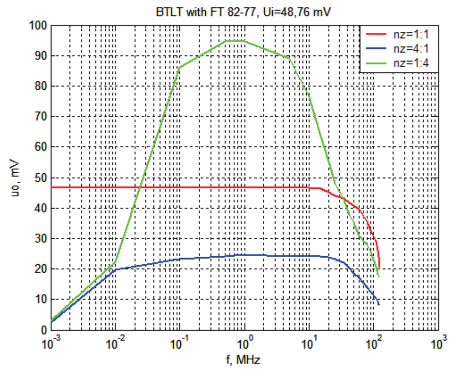

Fig. 5. AFR of BTLT with ferrite core FT82-77, with 5 twists per 1 cm when U_1=48,76 mV

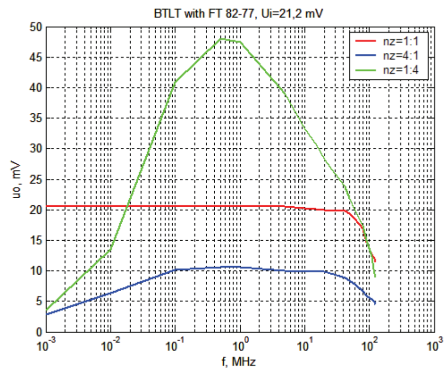

Fig. 6. AFR of BTLT with ferrite core FT82-77, with 5 twists per 1 cm when U_1=21,2 mV

From the presented AFR of BTLT with ferrite core Amidon FT82-77 with 5 twists per 1 cm, it has been found that:

- when transmission coefficients *nz*=1:4 and *nz*=4:1 with 5 twists there is a drop of AFR in the range of low frequencies.

In both cases the permeability of ferrite does not exert significant influence on the low-frequency range, because when *nz*=1:4 there is also Au=1:2, and when *nz*=4:1 – Au=2:1 what reduces the value of the created magnetic flux in the ferrite core;

- when *nz*=1:4 the shape of AFR resembles that of the bandpass filter and the drops at low and high frequencies are more pronounced (steeper). In this case the section with a uniform transmission coefficient in the transmitted band is very small which determines the very narrow transmitted frequency band.

Conclusion: The transmitted frequency band narrows with increasing the number of twists.

C. Experimental results of BTLT with toroidal ferrite core Amidon FT114-77 with nz=1:1, nz=4:1 and nz=1:4

Amplitude-frequency responses of BTLT with ferrite core Amidon FT114-77 are presented in graphical form when input voltages are U_1=48,76 and U_1=21,2 mV with 3 twists per 1 cm respectively in Fig. 7 and Fig. 8.

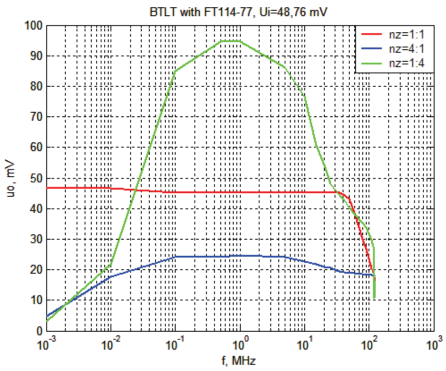

Fig. 7. AFR of BTLT with ferrite core FT114-77, with 3 twists per 1 cm when U_1=48,76 mV

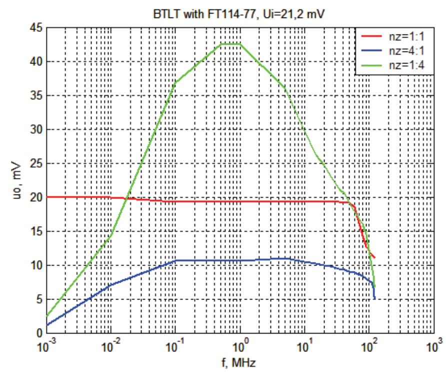

Fig. 8. AFR of BTLT with ferrite core FT114-77, with 3 twists per 1 cm when U_1=21,2 mV

From the experimental studies carried out and their results obtained, it is established that when *nz*=1:1 in the frequency range 1÷30 kHz, the transmission coefficient is a bit higher compared to that in the transmitted band of ferrite core. This is due to the larger size of the used ferrite core and the greater length of transmission lines.

Conclusion: The type of amplitude-frequency response is determined by the method of connecting transmission lines to the source and load, i.e. by *nz*, and when *nz*≠1:1, are established slopes in the low-frequency and high-frequency field. When *nz*=1:1 a wider frequency band is ensured due to the extended low-frequency and high-frequency range.

Amplitude-frequency responses of broadband transmission line transformers with ferrite core Amidon FT114-77 with 5 twists per 1 cm are shown in Fig. 9 and Fig. 10 respectively when input voltages U_1=48,76 mV and U_1=21,2 mV.

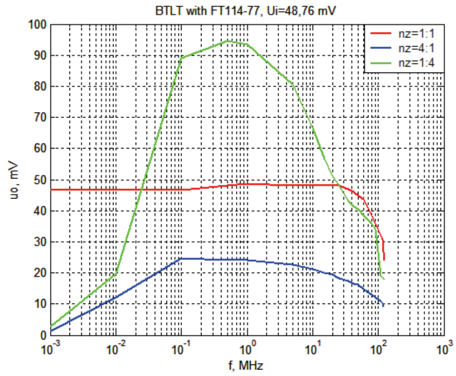

Fig. 9. AFR of BTLT with ferrite core FT114-77, with 5 twists per 1 cm when U_1=48,76 mV

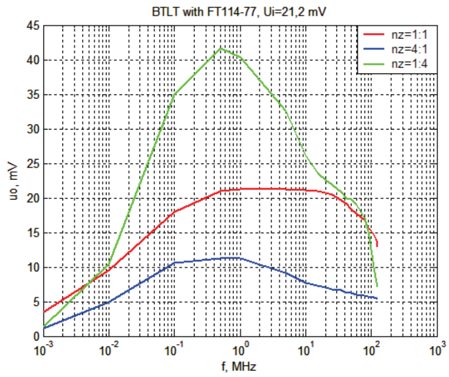

Fig. 10. AFR of BTLT with ferrite core FT114-77, with 5 twists per 1 cm when U_1=21,2 mV

On the basis of obtained amplitude-frequency responses in Fig. 9 and Fig. 10 it has been found that:

- when *nz*=1:1, the transmission coefficient in the frequency response 1÷20 MHz is slightly increased;
- when *nz*=1:4, there is no part in which the transmission coefficient is even. The slopes of growth and drop are more pronounced when the input voltage is lower;
- There are slopes with different drop of amplitude-frequency responses at lower value of operating voltage. For cases presented in Fig. 10 the steepness of these slopes decreases in both cutoff-frequency ranges.

The qualitative parameters of BTLT with ferrite toroidal cores Amidon FT82-77 and FT114-77 with 3 and 5 twists per 1 cm when U_1=48,76 mV and U_1=21,2 mV are presented in the generalized Table II.

TABLE II
PARAMETERS OF IMPLEMENTED BROADBAND TRANSMISSION LINE TRANSFORMERS

Number of turns	U_1, mV	*nz*	BTLT with Amidon FT82-77			BTLT with Amidon FT114-77		
			fb, kHz	fh, MHz	Δf, MHz	fb, kHz	fh, MHz	Δf, MHz
3 twists per 1 cm	48,76	1:1	1	120	119,99	1	73	72,99
		4:1	1	78	77,99	10	125	124,99
		1:4	50	14	13,95	80	13	12,92
	21,20	1:1	1	125	124,99	1	78	77,99
		4:1	1	110	109,99	40	100	99,96
		1:4	1	10	9,99	80	8	7,92
5 twists per 1 cm	48,76	1:1	1	90	89,99	1	100	99,99
		4:1	60	6	5,94	30	35	34,97
		1:4	70	13	12,93	70	10	9,93
	21,20	1:1	1	90	89,99	80	100	99,92
		4:1	60	55	54,94	80	3	2,92
		1:4	90	9	8,91	70	7	6,93

From the obtained comparative assessment of AFR and parameters of BTLT with 3 and 5 twists per 1 cm it is established that:

- when *nz*=1:4 and the ferrite core (FT114-77) is larger, narrowing of AFR is observed as the section with a uniform transmission coefficient remains the same;
- when *nz*=1:1 there is a difference in the transmission coefficient of the order of 6 %;
- when *nz*=4:1 for BTLT with ferrite core FT82-77, a larger section of the transmitted band with the same value of transmission coefficient is established, compared with BTLT with ferrite core FT114-77;
- when *nz*=4:1 for BTLT with ferrite core FT114-77 and 5 twists, the transmitted frequency band lightly shifts to the range of the low frequencies - Fig. 4.10.

Conclusion: A significant difference between AFR of BTLT with ferrite cores FT88-77 and FT114-77 in individual *nz* has not been found. The existing differences when there are 5 twists per 1 cm are smaller than those when the twists are 3. The minimum differences in AFR of BTLT with ferrite cores FT88-77 and FT114-77 with 3 and 5 twists per 1 cm are attributable to manufacturing tolerances of the parameters of the used ferrites - μ_r и A_L.

In Fig. 11 is presented a comparative assessment of the obtained amplitude performances (AP) for different implementations of broadband transmission line transformers with ferrite core FT82-77 with 3 and 5 twists per 1 cm when f=1 MHz.

From the obtained AP it is established that:

- the nature of AP in all cases is linear;
- the difference in AP between BTLT with ferrite core FT82-77 with 3 and 5 twists per 1 cm is minimal.

III. CONCLUSION

This paper presents a comparative assessment (in graphical and tabular form and analysis) of the experimentally obtained AFR and qualitative parameters of implemented BTLT with ferrite toroidal cores manufactured by the firm Amidon FT82-77 and FT114-77 with 3 and 5 twists per 1 cm for various values of the submitted input voltage and different *nz* – 1:1, 4:1 and 1:4.

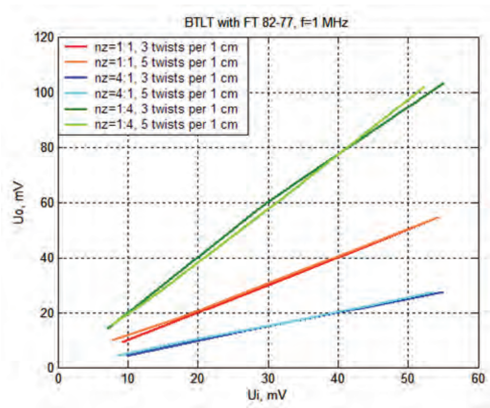

Fig. 11. Comparative assessment of AP of BTLT with ferrite core FT88-77 with 3 and 5 twists per 1 cm when f=1 MHz

The obtained results can be used for optimization of the values of model parameters and qualitative parameters of simulation models of broadband transmission line transformers, and in practice.

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