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Summing Signals of Push-Pull Broadband Amplifier Modules

Boyan D. Karapenev[1] and Ilya N. Nemigenchev[2]

***Abstract* – This paper presents the qualitative parameters of two identical push-pull broadband amplifier modules implemented with different bipolar transistors and broadband transformers, working in modes: classes B and AB, and five variants for adding their signals by measuring: amplitude characteristics, transmission coefficient, dynamic range and amplitude-frequency characteristics (frequency bandwidth). The received results and parameters of experimental researches have been generalized and presented in graphical and tabular form. Comparative analysis of the experimental results obtained, as well as conclusions and recommendations for application of constructed Variants have been done.**

***Keywords* – summing, signals, push-pull, broadband, amplifier module, broadband transformer.**

I. INTRODUCTION

Up-to-date broadband amplifiers are characterized by their high output power and great efficiency. Specific requirements are set to them with respect to the amplitude-frequency characteristics (AFC), efficiency, gain coefficient in the bandwidth, etc.

Power amplifiers of up to several kW and frequency range up to 100MHz are most frequently constructed on the basis of separate broadband amplifier modules (BAM), made up of bipolar or field-effect transistors and broadband transformers. The output power of such a module reaches 100÷200W. To reach the required level of output power, broadband amplifiers are constructed by summing up the signals of the individual amplifier modules.

II. IMPLEMENTATION AND STUDYING OF BAMS

Broadband amplifier modules are widely used in constructing radio transmitters of wide frequency range. Since the output power of the final stage exceeds considerably the power of an individual amplifier module, it is necessary to implement the principle of summing up the powers of a number of amplifier modules on a common load.

The following ways of summing up signals were used most widely [1], [2], [7]:

- by direct connection of the amplifier modules: parallel and push-pull;
- by bridge connections;
- by means of high-frequency broadband transformers.

A push-pull broadband amplifier module has been designed, operating in modes of B and AB classes. Its schematic diagram is shown in Fig. 1 [6]. The preset basic performance characteristics are: U_{CC}=15V, P_0=40W, $R_i=R_0=R_L=50\Omega$, A_U=15, f_B=1MHz and f_H=25MHz. Design calculations have been done and the broadband transmission line transformers (BTLT) used have been constructed [5], [2]. Transformers Tp_1 and Tp_4 provide the required matching at the input and at the output of the amplifier module, and the necessary transformation of the circuit impedances is accomplished by means of Tp_2 and Tp_3 - 4:1 and 1:4, respectively.

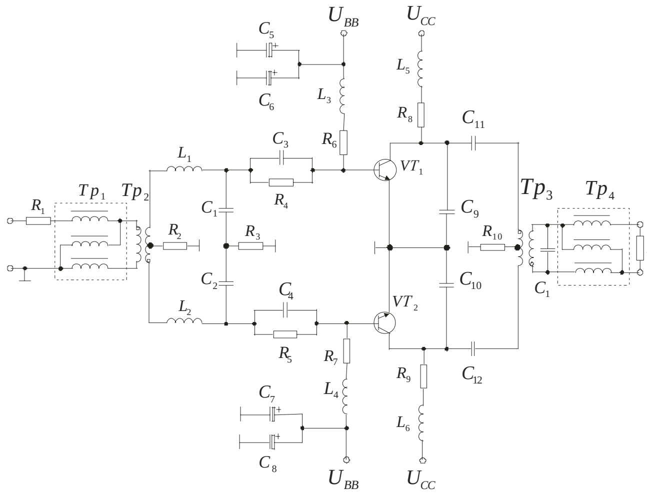


Fig. 1. Schematic diagram of a push-pull BAM

Two identical BAMs (BAM1 and BAM2) have been constructed and studied. They operate in modes of B and AB classes, respectively with transistor couples KT920B and MRF454.

A. Experimental study of BAM1

To find out the effect of the transistors used, experimental study of BAM1 constructed with transistor couples KT920B and MRF454, respectively, has been carried out. The obtained amplitude characteristics (AC) and amplitude-frequency characteristics (AFC) for operation mode of class B are shown in common coordinate systems in Fig. 2 and Fig. 3, respectively.

[1]Boyan D. Karapenev is with the Department of Communication Technics and Technology, Technical University - Gabrovo, Bulgaria, E-mail: bkarapenev@tugab.bg

[2]Ilya N. Nemigenchev is with the Department of Communication Technics and Technology, Technical University - Gabrovo, Bulgaria, E-mail: nemig@tugab.bg

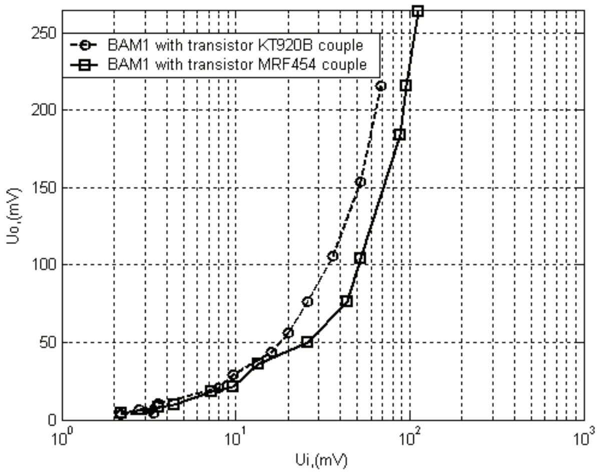


Fig. 2. AC of BAM1 in operating mode of B class, constructed with transistors KT920B and MRF454

It has been found out that when constructing BAM1 with KT920B transistors, larger linearity of characteristics is obtained compared with the construction with MRF454, for a greater dynamic range D_{KT920B}=4,25 with respect to KT920B D_{KT920B}=4,13, and voltage gain Au_{K920B}=3,17 and Au_{MRF454}=2,37, respectively.

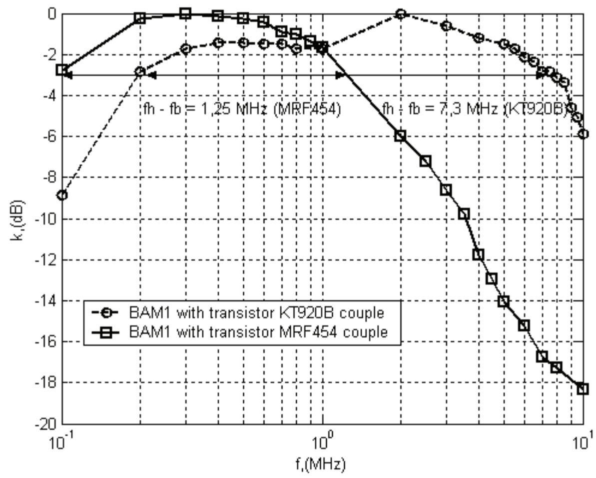


Fig. 3. AFC of BAM1 in B class operating mode, constructed with KT920B and MRF454 transistors

From the characteristics given in Fig. 3 it can be seen that there is a great difference in the frequency bandwidth Δf_{KT920B}=7,3 MHz and Δf_{MRF454}=1,25 MHz, respectively, which is very impressive. It is due to the difference in the catalogue parameters of the transistors used, stray capacitances and inductances.

When constructing input and output BTLT with ferrite toroidal cores of various sizes and respectively various number of windings, AFC of analogous type are the result. Table 1 shows a comparative evaluation of the performance characteristics of each constructed variant.

TABLE I
BASIC PERFORMANCE CHARACTERISTICS

Variant №		1	2
Input transformer		12,7x4,8mm–10 wdg.	12,7x4,8mm –10wdg
Output transformer		**29x7,5mm – 21wdg.**	**21x6,35mm – 17wdg**
transistors **KT920B**	D	Uimin=16mv Uimax=68mV D=4,25	Uimin=18,4,mV Uimax=76mV D=4,13
	Au	3,17	2,78
	Δf	(7,5-0,2)=7,3MHz	(6-0,18)=5,82MHz
Transistors **MRF454**	D	Uimin=44mV Uimax=182mV D=4,13	Uimin=20mV Uimax=70mV D=3,5
	Au	2,37	2,31
	Δf	1,25MHz	0,9MHz

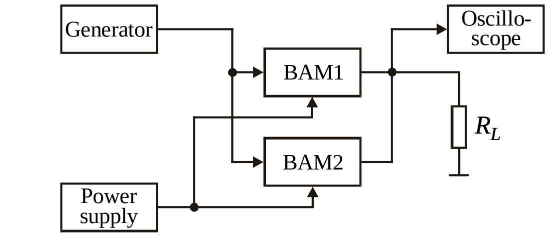
Variant №		3	4
Input transformer		12,7x4,8mm – 10wdg.	12,7x4,8mm -10wdg.
Output transformer		**21x6,35mm – 10wdg.**	**12,7x4,8mm -10wdg**
transistors **KT920B**	D	Uimin=28mv Uimax=144mV D=5,14	Uimin=36,mV Uimax=72mV D=2
	Au	3,31	3,16
	Δf	(5-0,25)=4,75MHz	(7-0,18)=6,82MHz
transistors **MRF454**	D	Uimin=30mV Uimax=112mV D=3,73	Uimin=34mV Uimax=68mV D=2
	Au	2,29	2,32
	Δf	(1,2-0,1)=1,1MHz	(1-0,16)=0,84MHz

Variant №		5	6
Input transformer		**21x6,35 mm – 10wdg**	**21,7x6,35mm-10wdg.**
Output transformer		**21x6,35mm – 17wdg.**	**29x7,5mm -21wdg.**
transistors **KT920B**	D	Uimin=10,4mv Uimax=64mV D=6,15	Uimin=8,8mV Uimax=36mV D=4,09
	Au	4	3,94
	Δf	(0,73-0,02)=0,71MHz	(0,8-0,02)=0,78MHz
transistors **MRF454**	D	Uimin=9,2mV Uimax=72mV D=7,82	Uimin=32mV Uimax=72mV D=2,25
	Au	2,61	2,41
	Δf	(0,75-0,03)=0,72MHz	(0,9-0,1)=0,8MHz

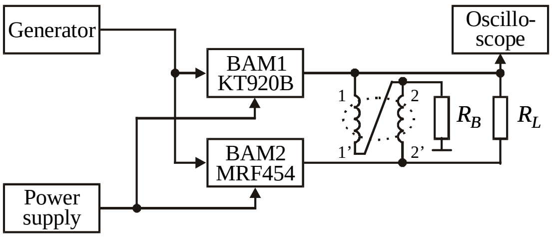
It follows from the above obtained results that the parameters and manufacturing tolerances of the transistors used, as well as the BTLT parameters have an effect on the performance characteristics of BAM by means of the ferrite toroidal core size, the number of windings of the transmission lines used, etc. (in this case a couple of twisted enameled conductors of d=0,62 mm).

B. Experimental studies and outcomes for summing and separating of signals for different connections of BAM1 and BAM2

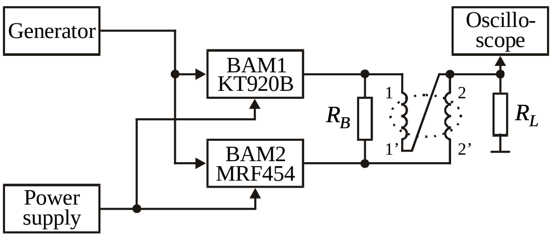
For separating and summing the signals of BAM1 and BAM2 constructed with transistors KT920B, and MRF454 or KT920B, respectively, in order to enhance the output power on a common load, 5 variants of their connection have been made [1], [2], shown in Fig. 4.



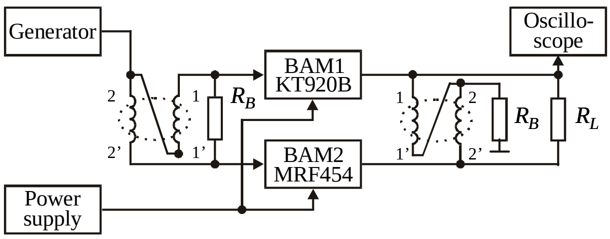
a - Variant 1



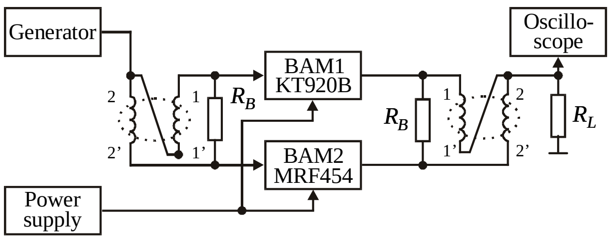
b - Variant 2



c - Variant 3



d - Variant 4



e - Variant 5

Fig. 4. Variants of connecting BAM1 and BAM2 constructed with transistors KT920B, and MRF454 or KT920B

Fig. 5 and Fig. 6 show a comparative evaluation and the graphs of AC and AFC, respectively for Variant 2 of connecting both push-pull BAMs, one of which is constructed with KT920B transistors, and the other - with MRF454 transistors with two BAMs constructed with couples of KT920B transistors each.

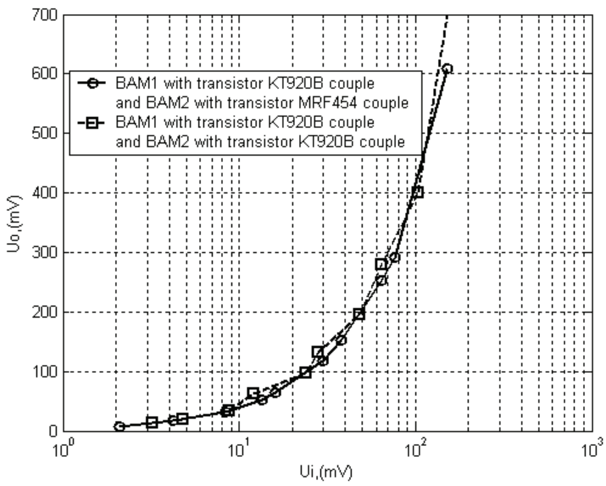


Fig. 5. AC when connecting both push-pull BAMs according to the diagram of Variant 2

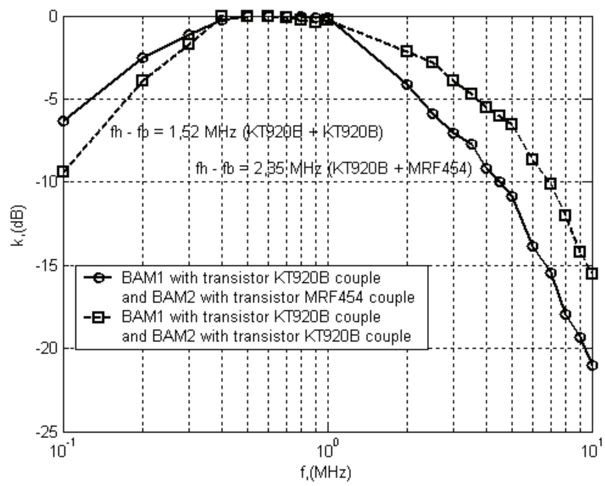


Fig. 6. AFC when connecting both push-pull BAMs according to the diagram of Variant 2

From the characteristics shown in Figs. 5 and 6 it has been found out that BAMs constructed with KT920B and MRF454 transistors and only with KT920B transistors, have identical AC, and the slopes of AFC are displaced to the region of lower frequencies.

The performance characteristics for the five Variants of connecting BAM1 constructed with KT920B transistors and BAM2 constructed with MRF454 are presented in Table 2. Table 3 compares their values for Variants 1, 2 and 3 to those obtained from studying both BAMs constructed only with KT920B transistors.

III. Results Analysis

The use of different couples of bipolar transistors when constructing push-pull BAMs (KT920B and MRF454 in BAM1) results in a considerable difference in the bandwidth 7,3 MHz and 1,25 MHz, respectively.

TABLE II
MAJOR PERFORMANCE CHARACTERISTICS FOR EACH VARIANT OF CONNECTING PUSH-PULL BAMS

Variant №		Variant 1	Variant 2	Variant 3	Variant 4	Variant 5
Input transformers 12,7x4,8mm -10 wdg.; Output transformers 29x7,5mm – 21 wdg.						
MRF454 and T920B	D	Uimin=96mv Uimax=236mV D=2,45	Uimin=38mV Uimax=152mV D=4	Uimin=76mV Uimax=156mV D=2,05	Uimin=52mV Uimax=112mV D=2,15	Uimin=90mV Uimax=212mV D=2,35
	Au	0,28	4	1,38	0,42	46,16
	Δf	(2,5-0,14)= =2,36MHz	(1,7-0,18)= =1,52MHz	(2,2-0,44)= =1,76MHz	(1,2-0,15)= =1,05MHz	(2,5-0,35)= =2,15MHz

TABLE III
COMPARISON OF THE MAJOR PERFORMANCE CHARACTERISTICS FOR VARIANTS 1, 2 AND 3 OF CONNECTING BAM

		Direct parallel	With BTLT	
№		Variant 1	Variant 2	Variant 3
Input transformers 12,7x4,8mm–10 wdg.; Output transformers 29x7,5mm – 21wdg.				
BAM with MRF454 and KT920B	D	Uimin=42mv Uimax=156mV D=3,71	Uimin=38mV Uimax=152mV D=4	Uimin=76mV Uimax=156mV D=2,05
	Au	1,61	4	1,38
	Δf	(2,2-0,4)=1,8MHz	(1,7-0,18)=1,52MHz	(2,2-0,44)=1,76MHz
BAM with KT920B and KT920B	D	Uimin=8,8mV Uimax=53,6mV D=6,09	Uimin=48mV Uimax=152mV D=3,16	Uimin=28mV Uimax=148mV D=5,28
	Au	0,68	4,63	0,59
	Δf	(2,7-0,25)=2,45MHz	(2,6-0,25)=2,35MHz	(1,3-0,8)=0,5MHz

The ferrite toroidal cores used do not have constant parameters in their operating frequency range preset by the manufacturer and their manufacturing tolerances are significant. It is required that their practical manufacture - number of windings, number of twists per unit of length, transmission line used, etc., should be executed with great accuracy and repetition of the key parameters.

The difference in the characteristics and parameters obtained as a result of constructing identical BAMs can reach up to 10% which requires their optimization. It can be fulfilled most easily by a change in the construction of BTLT.

In order to provide a larger frequency bandwidth, the voltage gain should be decreased. A balance at Au_{KT920B}=4,63, Δf_{KT920B}=2,35 MHz and Au_{MRF454}=4, Δf_{MRF454} =1,52 MHz was reached during the experimental studies.

The experimental studies conducted show that a broader frequency band at lower voltage gain can be achieved with a push-pull BAM compared to a single-ended BAM [3].

The BTLT used which help in separating and summing of signals by individual BAMs for summing up their powers on a common load, also have a strong effect on the performance characteristics obtained. It is of great importance for them to match accurately the input and output impedances which is a prerequisite for making them broadband as required.

A disadvantage of the developed Variants of summing up signals of push-pull BAMs appears to be the great number of BTLT used, which make construction difficult, increase the size, limit the frequency bandwidth and lead to an increase in their manufacturing tolerances.

IV. CONCLUSION

The transistors used, the construction and parameters of the BTLT used and the way of connecting BAMs for summing up signals by criteria of certain performance characteristics: gain coefficient, dynamic scope, and frequency bandwidth, determine the performance characteristics of the constructed amplifier.

The construction of broadband amplifiers by modular principle has the following advantages: identical parameters, interchangeability, easy matching with the help of BTLT, high reliability and low cost.

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