AN10869

Broadband DVB-T UHF power amplifier with the BLF888

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Document information

Info	Content
Keywords	BLF888, DVB-T, UHF broadcast
Abstract	This application note describes the design and performance of a DVB-T UHF power amplifier using the BLF888.

Revision history

Rev	Date	Description
01	20100525	Initial version

1. Introduction

For the past few years, new product design in the broadcast industry has been dominated by emerging digital modulation standards. A specific example is broadcast television, where many new transmitter systems are currently being set up as part of the conversion to digital terrestrial television.

The BLF888 is a UHF LDMOS power transistor intended for the broadcast transmitter market. It can deliver 110 W DVB-T average power over the full UHF band from 470 MHz to 860 MHz at a CCDF of 8 dB (0.01 %). The transistor is also capable of handling analog TV (ATV) signals. The average power delivered will be dependent on cooling conditions.

Today, UHF transmitter design focuses on increasing efficiency and output power, while reducing size. To achieve these goals, the next generation of UHF transistors must deliver greater power levels, increased efficiency and higher gain, and the size of application boards needs to be reduced. The BLF888 meets these requirements.

This report describes a broadband application incorporating the BLF888, built on a small form factor board with a total size of 105 mm × 50 mm.

2. Circuit description

The BLF888 broadband application circuit is shown in Figure 1. It is a Class AB common source amplifier. Circuit dimensions are 105 mm × 50 mm (including the transistor). If the connectors are excluded, the dimensions are 95 mm × 50 mm. The PCB material is Taconic RF35 (ε_r = 3.5) with a thickness of 0.76 mm.

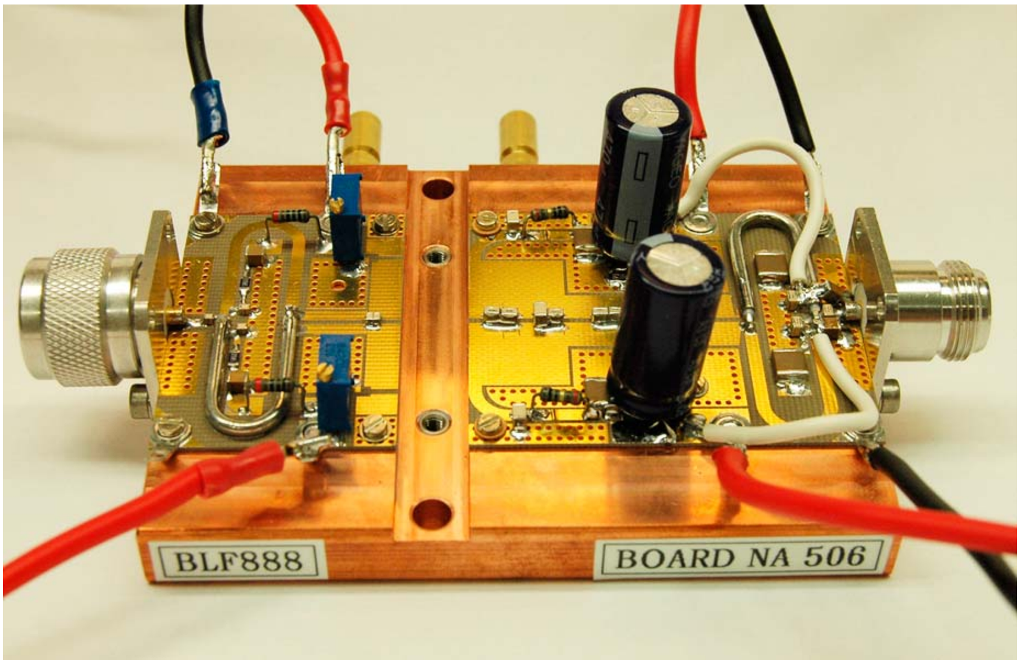

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Fig 1. BLF888 broadband application circuit

A schematic diagram of the application design is shown in Figure 2. The output consists of two microstrip lines per side, L1 and L2, and a balun B1 (25 Ω). C1 to C12 are used to match the transistor impedance to the input impedance of the balun (25 Ω). The balun converts the 25 W differential impedance to a 50 Ω asymmetrical impedance at the output. The length of the balun is approximately λ/8 at the UHF middle frequency. Microstrip line L3 is connected to the differential input of the balun to improve the symmetry of the impedance to ground.

L5 in combination with C17 and C18 improves matching at the lower UHF frequencies. C9 to C12 influence the common mode impedance and improve the harmonic behavior. R1 and R2 were added for low frequency damping.

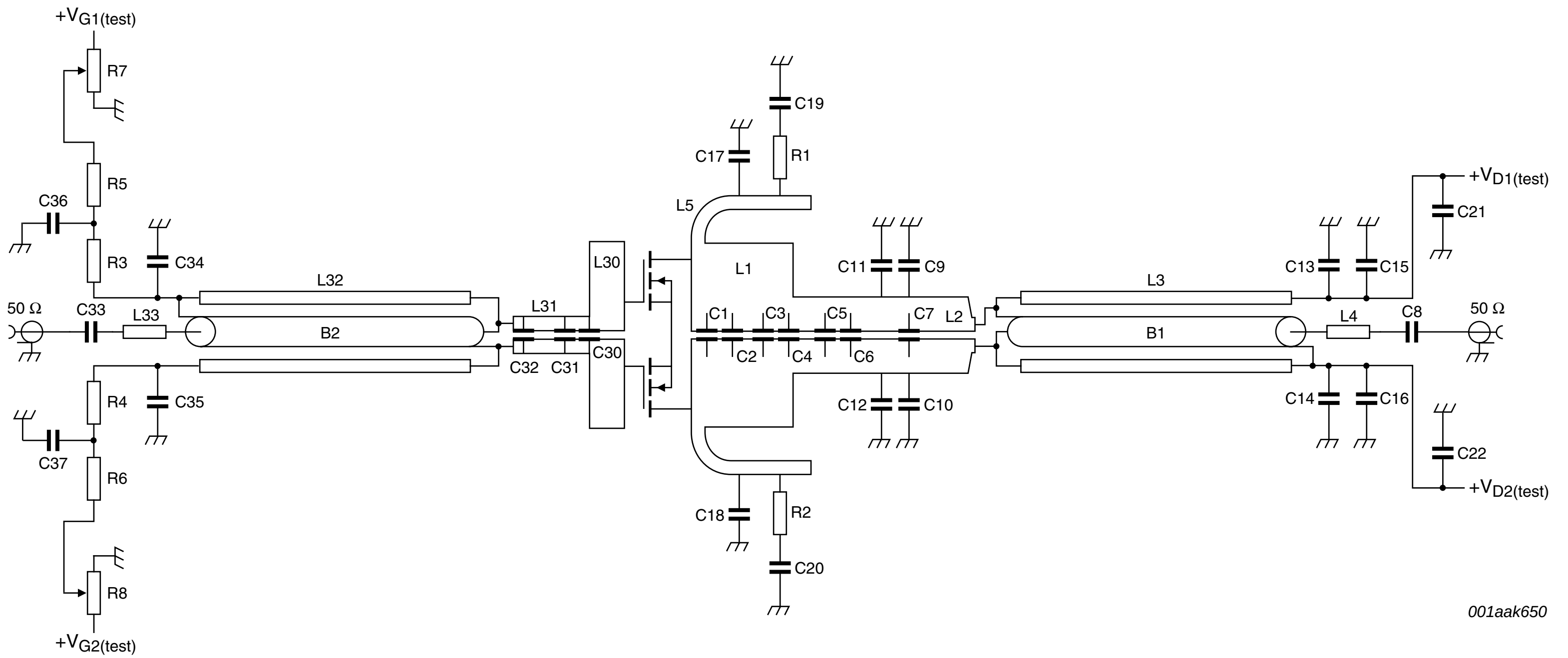

Fig 2. Class-AB common-source broadband amplifier

The input also consists of two microstrip lines, L30 and L31, and a balun B2 (25 Ω). C34 and C35 are RF decoupling capacitors for the balun. The transistor gate supply is connected via an RC network consisting of resistors R3 to R6, along with C36 and C37. This RC network performs a damping function that helps improve stability. Microstrip line L32 performs the same function at the input as microstrip line L3 at the output.

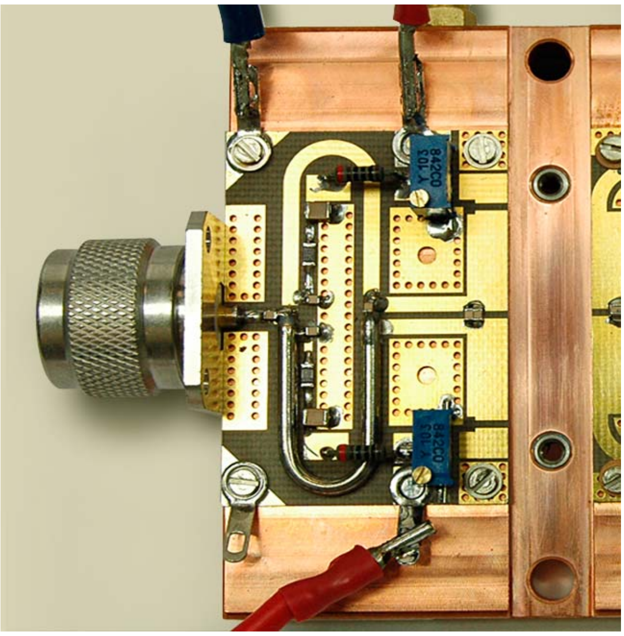

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Fig 3. Input circuit

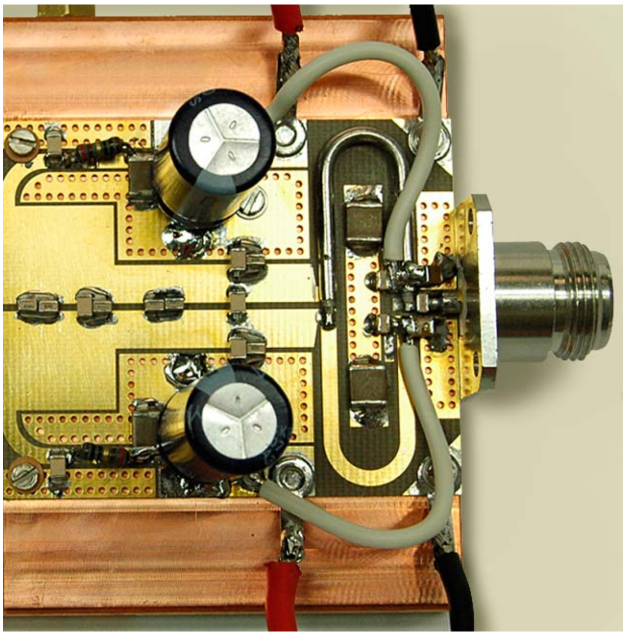

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Fig 4. Output circuit

3. Design and Simulation

3.1 BLF888 impedance and simulation data

The impedance data detailed in Figure 5, Figure 6 and Figure 7 was used as a starting point in the development of the broadband circuit.

The push-pull and common mode simulation results for the broadband application circuit are shown in Figure 8 and Figure 9 respectively. The low impedance in the second harmonic band (940 MHz to 1720 Mhz) is of particular significance in the simulation. The resonance peaks in common mode can be shifted via capacitors C9 and C12 (see Figure 2). A high second harmonic impedance will result in significant power and efficiency losses.

3.1.1 Impedance data

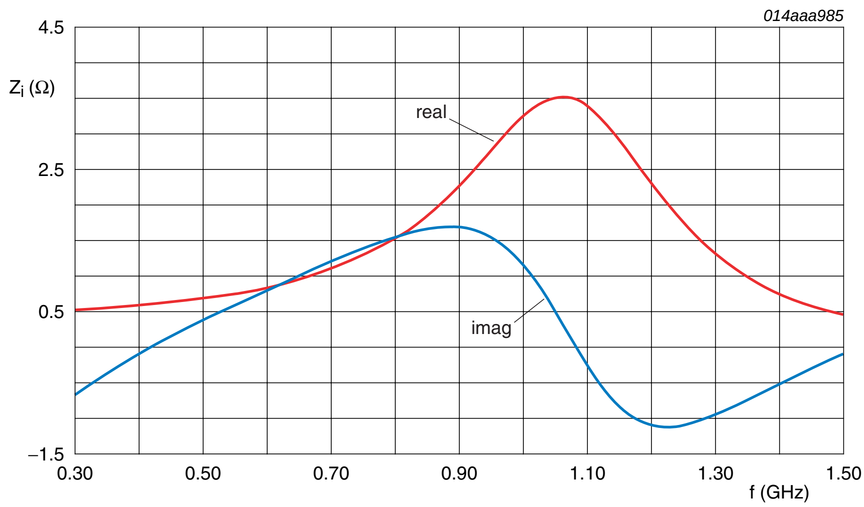


Fig 5. Input impedance; one side

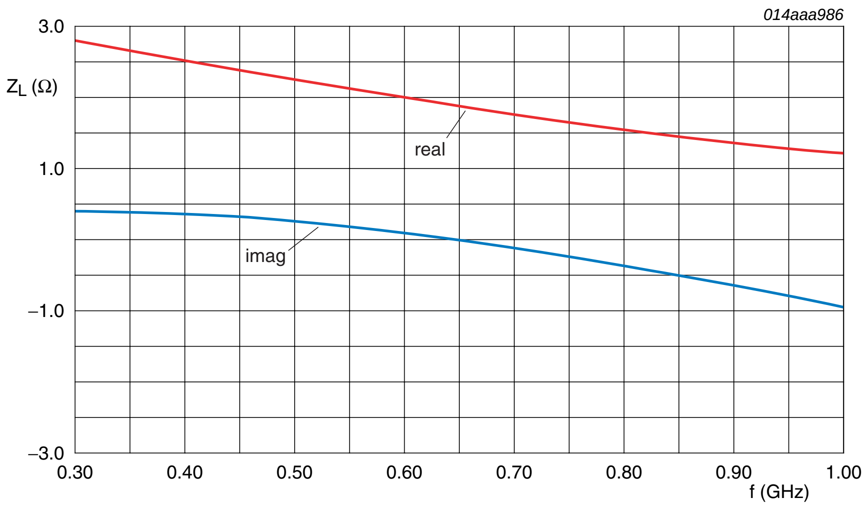


Fig 6. Output impedance; P_O = 600 W (total); one side

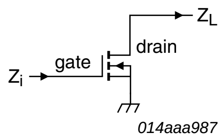
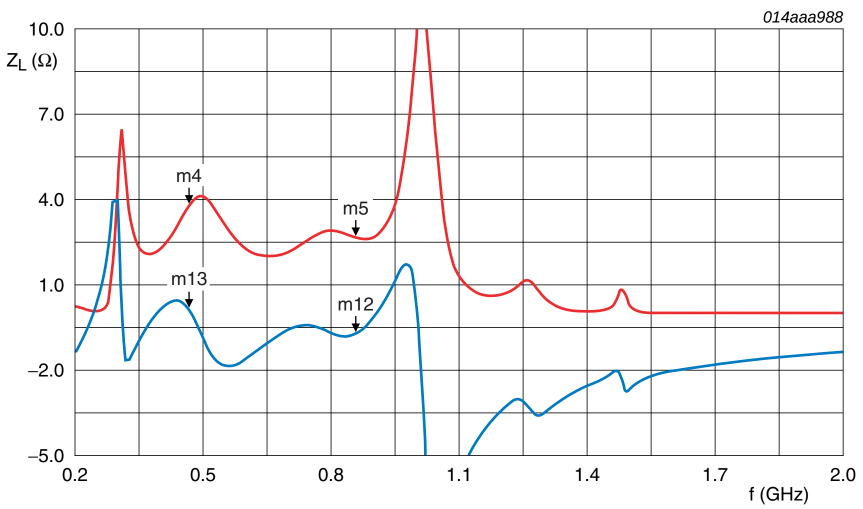


Fig 7. Definition of transistor impedance: Z_i = input impedance, Z_L = load impedance

3.1.2 Simulation data



m4: 470 MHz, Zp (real) = 3.813 m5: 880 MHz, Zp (real) = 2.640

m13: 470 MHz, Zp (imaginary) = 0.067 m12: 860 MHz, Zp (imaginary) = 0.715

Fig 8. Internal drain impedance; one side, push-pull mode

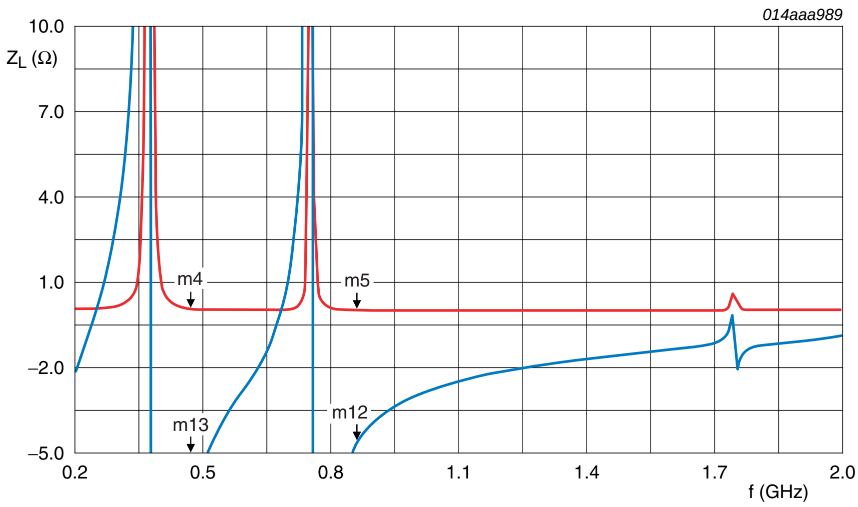


Fig 9. Internal drain impedance; one side, common mode

3.2 Bias and decoupling circuit

The RF amplifier is sensitive to oscillations during mismatch. Therefore special care was taken to ensure adequate low frequency clamping at both the input and at the output. Two clamping resistors, R1 and R2, were added at the output for this purpose. Also, the supply is connected to the balun at the output. At the input, clamping is achieved via the RC network connected to the balun.

3.3 Thermal considerations

The circuit is designed to deliver 110 W DVB-T average power. The transistor can also handle CW, 2-Tone and analog TV signals. However the power dissipation and heat generated by the transistor and the circuit can be excessively high, especially with CW and analog TV signals. The maximum temperature the transistor can handle is 200 °C. The electromagnetic (see Ref. 1) and lifetime (20 years minimum) restrictions must also be respected.

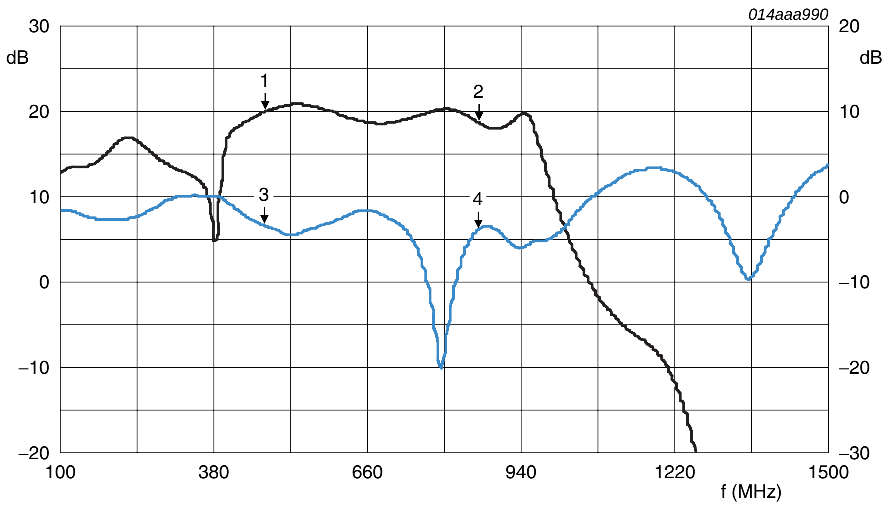
In this circuit, power dissipation is limited by the matching capacitors C1 and C2, and the balun (P_{max} = 150 W (average)). For short-term testing, the circuit can handle CW power levels up to 450, W as can be seen from the large signal measurement results (see Section 4.2).

4. Test results

4.1 Small signal measurements

The small signal measurement results for the test board are shown in Figure 10.

Special care is needed when designing low frequency decoupling at both input and output. Even more damping than was applied in the test circuit would be needed to achieve a circuit that was stable under all conditions.



(1) S21: 469.25 MHz (2) S21: 859.5 MHz (3) S11: 469.23 MHz (4) S11: 859.5 MHz

Fig 10. BLF888 small signal measurement; V_{DS} = 50 V, I_{Dq} = 2 A; both sides

4.2 Large signal measurements

The test circuit was evaluated for DVB-T (110 W average), 2_Tone (100 W to 250 W average), pulsed, CW (100 W to 450 W) and Analog TV (ATV, 200 W average at 45 V).

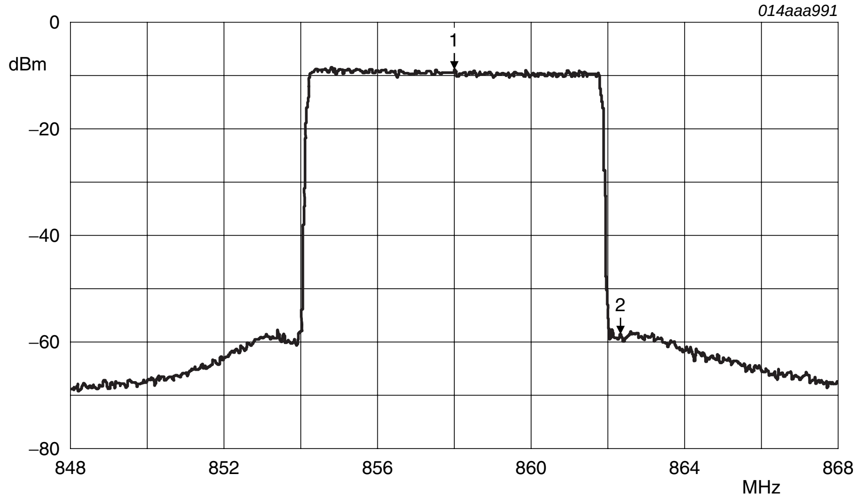
The measurement results are shown in Figure 11 to Figure 16. All measurements were taken at V_{DD} = 50 V, I_{Dq} = 1.3 A (except for the ATV measurement) and T_{water} = 25 °C (water-cooled test module).

The analog TV measurements were taken at 200 W average output power. The supply voltage was lowered to 45 V to improve efficiency and reduce power dissipation. Higher supply voltages of up to 50 V are possible, but the circuit would need to be redesigned to handle these levels. Cooling of the transistor becomes critical at higher levels. Soldering the transistor will lower the junction temperature significantly.

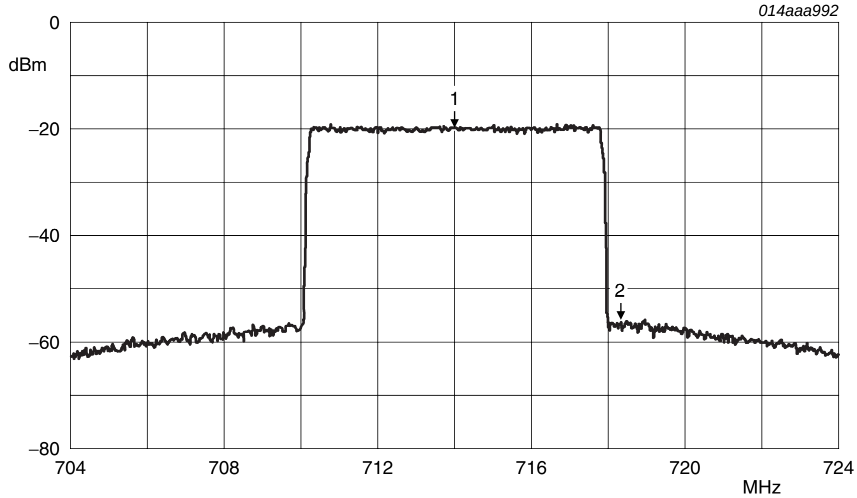
4.2.1 DVB-T

The target for the broadband circuit was to achieve average output power ($P_{L(AV)}$) of 110 W with a Peak-to-Average power Ratio (PAR) of 8 dB at a CCDF of 0.01 %. This target was met over the entire frequency range from 470 MHz to 860 MHz. Lead contact and capacitor positioning were extremely important in ensuring the target was met at the critical higher UHF frequencies (above 800 MHz). Shoulder distance is less than –30 dBc and gain is greater than 19 dB over the entire frequency band.

Drain efficiency (η_D) is greater than 27.5 % and is typically 29 %. Efficiency at the less responsive frequencies can be improved by lowering the supply voltage (the margin of the PAR at the less responsive frequencies in terms of η_D is wide enough to allow the supply voltage to be lowered, except at the very highest frequencies).

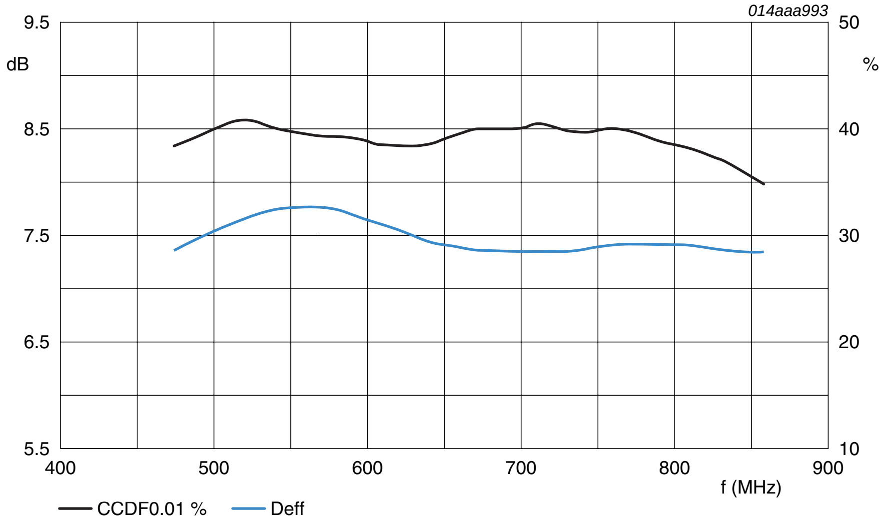


a. Input spectrum DVB-T 8k; $\Delta f_{(2-1)}$ = 4.3 MHz (–50 dB)

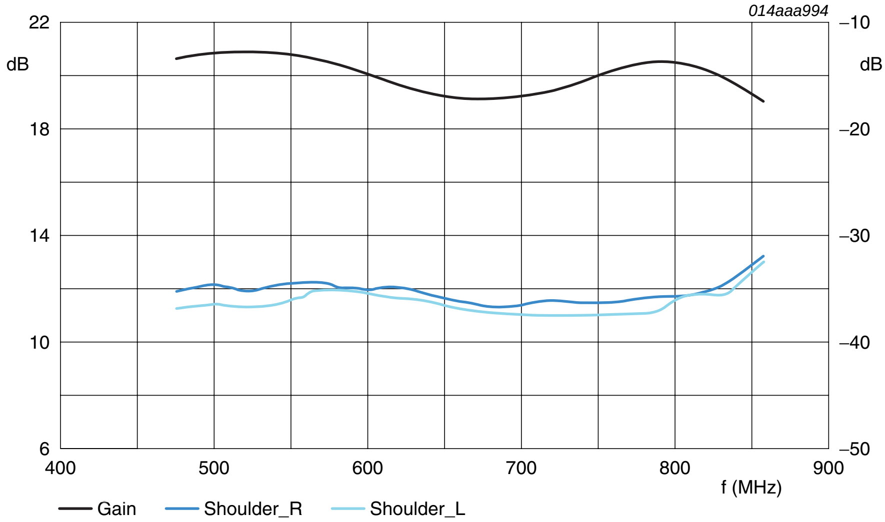


b. Output spectrum DVB-T 8k with BLF888 @ 714 MHz/110 W (average); $\Delta f_{(2-1)}$ = 4.3 MHz (–36.5 dB)

Fig 11. BLF888 large signal measurement: DVB-T with PAR of input signal = 9.5 dB at 0.01 % probability on CCDF



a. CCDF 0.01 % + drain deficiency

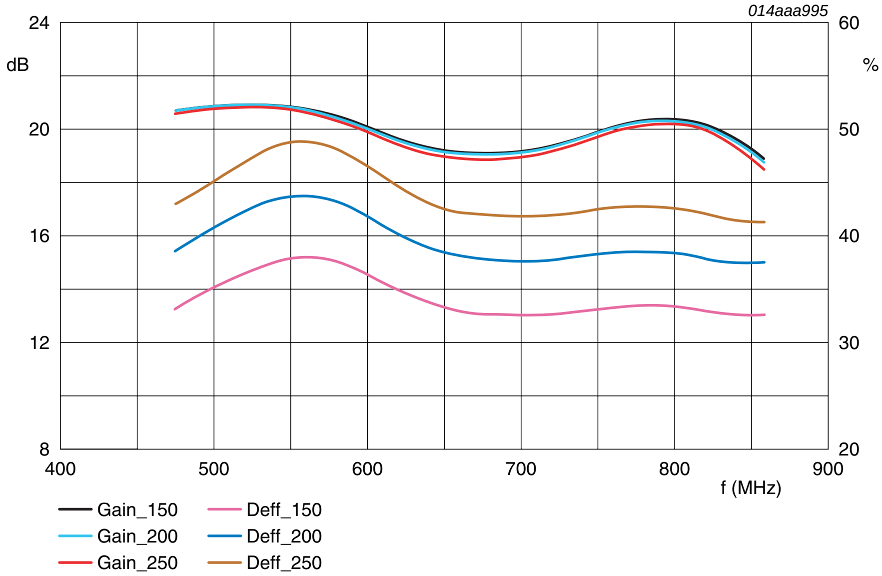


b. Gain + shoulder distance (4.3 MHz from f_c)
Shoulder measured in dBc via a delta marker

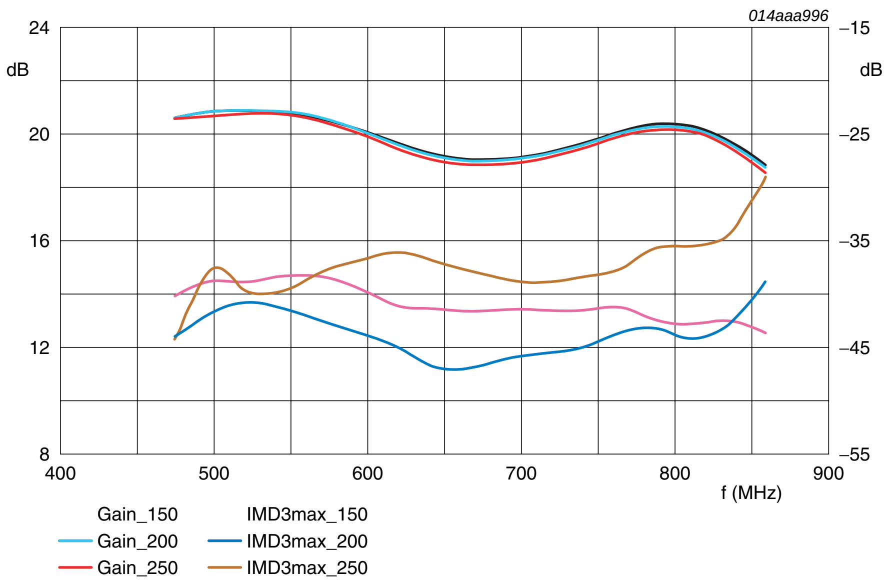
Fig 12. BLF888 large signal measurement: V_{DS} = 50 V, I_{Dq} = 1.3 A, T_{water} = 20 °C (water-cooled copper heatsink)

4.2.2 2-tone

Measurements were taken at $P_{L(AV)}$ = 150 W to 250 W (average). IMD3 levels are well below –30 dBc except at the highest frequencies at 500 W PEP. At these power levels, drain efficiency > 40 % over the entire UHF band.



a. 2-tone, gain and drain efficiency

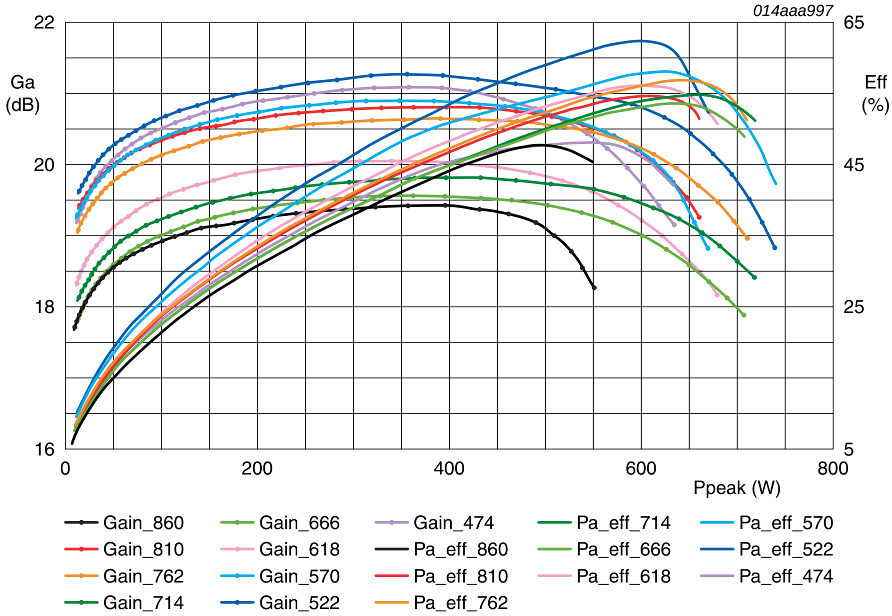


b. 2-tone, gain and IMD3 (max)

Fig 13. BLF888 large signal measurement: 2-tone broadband measurement at different $P_{L(AV)}$ levels (150 W to 250 W); V_{DS} = 50 V, I_{Dq} = 1.3 A, T_{water} = 20 °C (water-cooled heatsink); ∆f = 100 kHz, 2 carriers with equal amplitude

4.2.3 Pulsed

Pulsed measurement results between 470 MHz and 860 MHz (duty cycle = 10 %, t_p =100 µs) are shown in Figure 14. This provides a clear illustration of the peak power capability of this circuit. The lowest peak power level (≈550 W) occurs at 860 MHz (which corresponds with the DVB-T results).

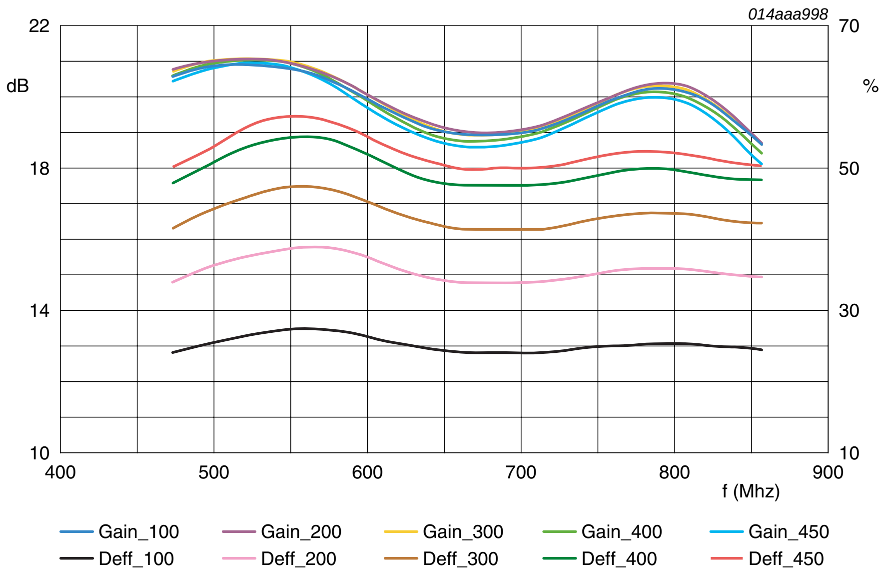


Gain + power added efficiency, t_p = 100 µs (pulse duration), δ = 10 % (duty cycle), T = 1 ms (period)
V_{DS} = 50 V, I_{Dq} = 1.3 A, T_{water} = 20 °C (water-cooled heatsink)

Fig 14. BLF888 large signal measurement: pulsed broadband measurement

4.2.4 CW

CW measurement results, evaluated at output power levels up to 450 W, are shown in Figure 15. The BLF888 can handle greater CW power levels but the output power was restricted due to thermal considerations. The test circuit was designed to deliver 110 W DVB-T average power and cannot operate continuously under CW conditions with $P_{L(AV)}$ >> 200 W.



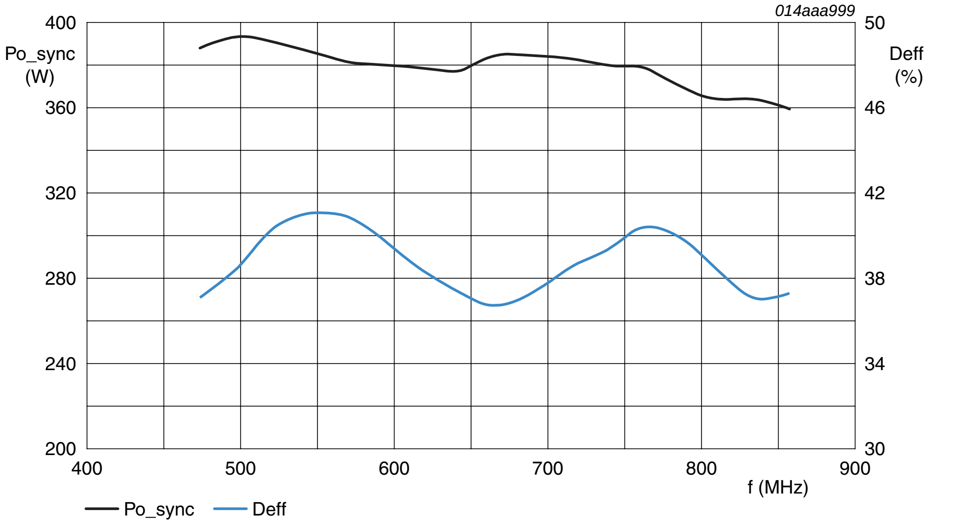
Gain + drain efficiency

V_{DS} = 50 V, I_{Dq} = 1.3 A, T_{water} = 20 °C (water-cooled copper heatsink)

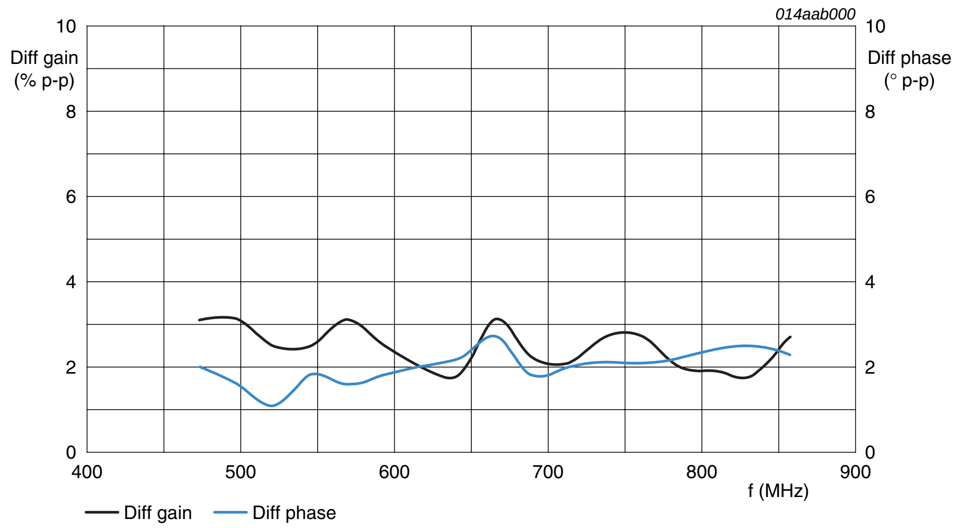
Fig 15. BLF888 large signal measurement: CW broadband measurement

4.2.5 ATV (PAL)

Measurements were taken at $P_{L(AV)}$ = 200 W, which corresponds to ≈350 W peak sync power at a nominal sync level of 27 %. If the sync compression is less, $P_{O(sync)}$ >> 350 W. $P_{L(AV)}$ was limited for thermal reasons (and V_{DS} was reduced to 45 V).



a. $P_{O(sync)}$ + drain efficiency at $P_{L(AV)}$ = 200 W, V_{DS} = 45 V



b. Differential gain (% p-p) + phase (° p-p) at $P_{L(AV)}$ = 200 W, V_{DS} = 45 V

(1) PAL BG, black video content, input sync expansion 33 %
$P_{O(AV)}$ limited for thermal reasons (test circuit designed for 110 W average DVB-T), I_{Dq} = 2 × 0.55 A, T_{water} = 20 °C (water-cooled copper heatsink)

Fig 16. BLF888 large signal measurement: ATV broadband measurement

5. Conclusion

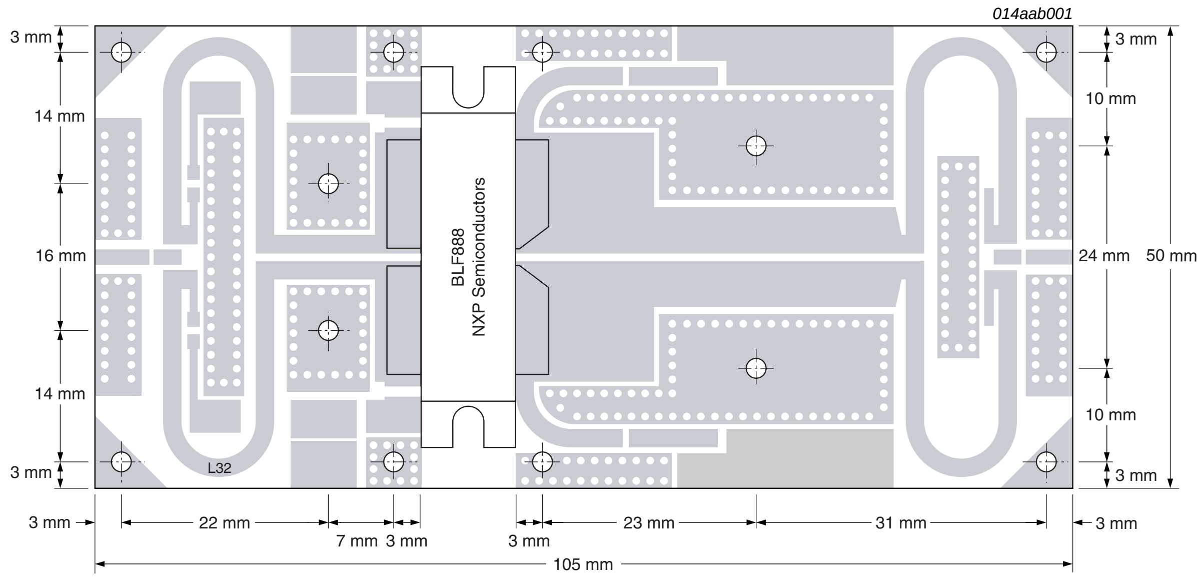
The BLF888 broadband application circuit presented in this report fulfils the following requirements:

- $P_{L(AV)}$ DVB-T > 110 W
- Efficiency > 27 % (typ. 29 %)
- Shoulder distance < –30 dBc (typ. –35 dBc)
- Gain > 18 dB (typ. 20 dB)

The circuit was designed for 110 W average DVB-T. The BLF888 is capable of delivering higher average power levels (e.g. in an ATV application). In such applications, special care must be taken to ensure adequate cooling is provided for the transistor and the circuit will need some redesign to handle the higher average power levels (e.g. the size of balun).

Critical aspects of this broadband design include the harmonic loading (especially the 2nd harmonic of frequencies below 500 MHz), lead contact (an 'air gap' will shift the impedance level significantly) and low frequency stability (several damping resistors were added).

6. Appendix A: PCB layout and Bill of Materials



All dimensions in mm; PCB input = 35 mm × 50 mm, PCB output = 60 mm × 50 mm, M2 holes

Fig 17. Dimensions of BLF888 broadband application circuit

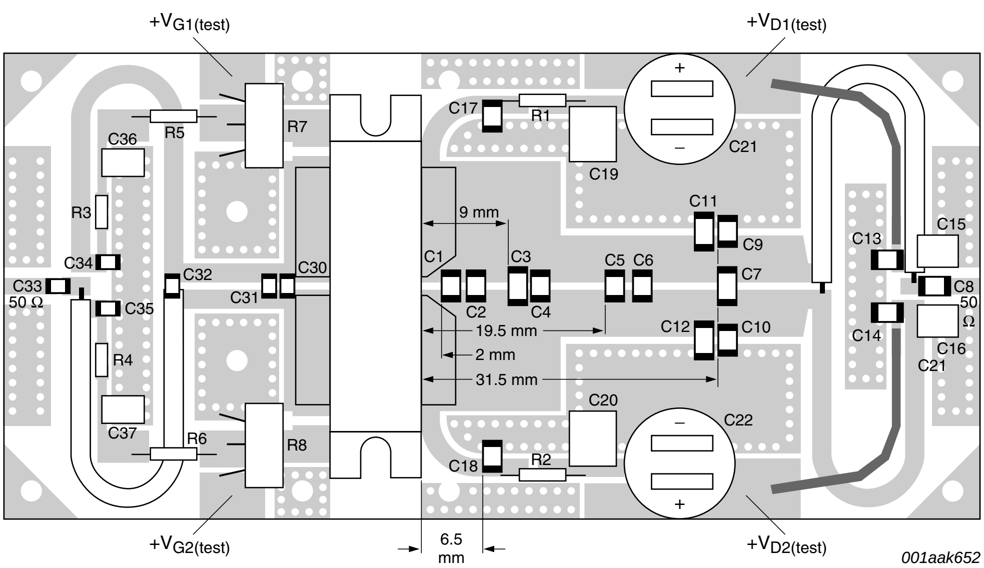


Fig 18. Component layout of BLF888 broadband application circuit

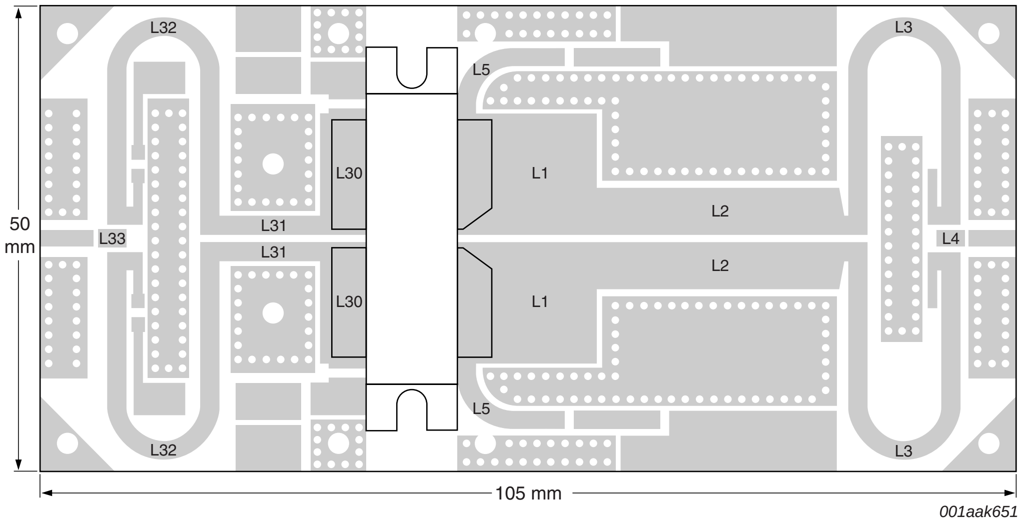


Fig 19. Microstrip layout of BLF888 broadband application circuit

Table 1. Parts list for BLF888 broadband application circuit

Component	Value	Type	Comment
Output			
C1	12 pF	ATC180R	
C2, C9, C10	10 pF	ATC180R	
C3	4.7 pF	ATC100B	
C4, C5, C6	8.2 pF	ATC180R	
C7	5.6 pF	ATC100B	
C8, C13, C14	100 pF	ATC180R	
C11, C12	2 pF	ATC100B	
C17, C18	100 pF	ATC100B	
C15, C16	4.7 μF	TDK C4532X7R1E475MT020U	50 V
C19, C20	10 μF	TDK C570X7R1H106KT000N	50 V
C21, C22	470 μF	electrolytic capacitor	63 V
R1, R2	10 Ω		
L1	15 mm × 13 mm	microstrip line	length × width
L2	26 mm × 5 mm	microstrip line	length × width
L3	49.5 mm × 2 mm	microstrip line	length × width
L4	3.5 mm × 1.7 mm	microstrip line	length × width
L5	9.5 mm × 2 mm	microstrip line	length × width
balun B1	semi-rigid coax Z_o = 25 Ω; 49.5 mm	UT-090C-25 (EZ 90-25)	
PCB		Taconic RF35, ε_r = 3.5	
		h = 0.76 mm; 50 mm × 50 mm	
		Cu plating 35 μm	

Table 1. Parts list for BLF888 broadband application circuit *...continued*

Component	Value	Type	Comment
Input			
C30, C31	10 pF	ATC100A	
C32	5.6 pF	ATC100A	
C33, C34, C35	100 pF	ATC100A	
C36, C37	4.7 μF	TDK C4532X7R1E475MT020U	
R3, R4	5.6 Ω		
R5, R6	100 Ω		
R7, R8	1 kΩ	potentiometer	
L30	13 mm × 5 mm	microstrip line	length × width
L31	11 mm × 2 mm	microstrip line	length × width
L32	49.5 mm × 2 mm	microstrip line	length × width
L33	3 mm × 2 mm	microstrip line	length × width
balun B2	semi-rigid coax Z_o = 25 Ω; 49.5 mm	UT-090C-25 (EZ 90-25)	
PCB		Taconic RF35, ε_r = 3.5	
		h = 0.76 mm; 35 mm × 50 mm	
		Cu plating 35 μm	

7. Abbreviations

Table 2. Abbreviations

Acronym	Description
CCDF	Complementary Cumulative Distribution Function
DVB	Digital Video Broadcast
DVB-T	Digital Video Broadcast - Terrestrial
UHF	Ultra High Frequency
CW	Continuous Wave
IMD3	Third-Order Intermodulation Distortion
PCB	Printed Circuit Board
PEP	Peak Envelope Power

8. References

[1] BLF888 data sheet

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10. Contents

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