RELIABILITY ANLYSIS OF 20KW SOLID-STATE AMPLIFIERS FOR CIADS

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Abstract

The technology of the solid-state amplifier will be applied by China Initial Accelerator Driven System (CIADS). 20 KW solid-state amplifiers are the basis of RF systems. This talk model 20 KW solid-state amplifiers with reliability block diagram (RBD). Through simulation, we find that the reliability function relative to redundancy approximates logarithm. There is an optimal solution between reliability and redundancy.

INTRUDUCTION

The solid-state amplifier has proved to be quite reliable as well as easy maintenance [1], so this technology will be used by CIADS. CIADS amplifiers have four types: 20 KW, 40 KW, 60 KW and 80 KW. 40 KW, 60 KW and 80 KW solid-state amplifiers are combined by 20 KW amplifier [2]. ADS has a very high requirement on reliability, and the requirement is difficult to realize [3]. Reliability analysis of 20 KW solid-state amplifiers is necessary for CIADS.

POWER COMBINATION AND ASSEMBLY

Strategic priority research program of CADS has applied 24 KW solid-state amplifier. The law of power combination is similar between 20 KW and 24 KW solid-state amplifiers. The schematic of 24 KW solid-state amplifiers is as Fig. 1.

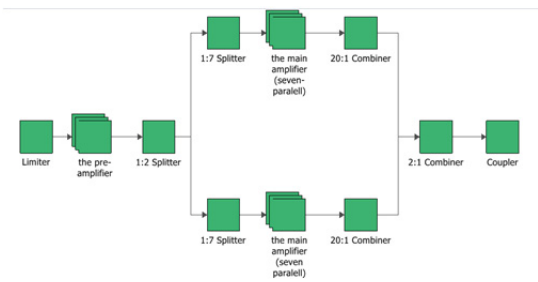

Figure 1: The schematic of 24KW solid-state amplifier (the pre-amplifier as Fig. 2 and the main amplifier an Fig. 3).

850 W amplifiers are the elementary unit of 24 mKW solid-state amplifiers. The small signal is magnified by limiter, and then is distribute to the pre-amplifier (eight-parallel amplifiers and only one running) by a 1:8 Splitter. Fourteen 1:3 Splitters are connected behind two 1:4 Splitters. The small signal is transmitted to forty 850W amplifiers to amplifier power. The style of redundancy is degradation of amplifiers. 29 of 40 amplifiers is running and this will satisfy the requirement of 24 KW. If one amplifier is fault, the control system will give a signal and increase the power of other amplifiers. The power of forty 850 W amplifiers is combined by 20:1 Combiner and 2:1 Combiner. The coupler monitor the power.

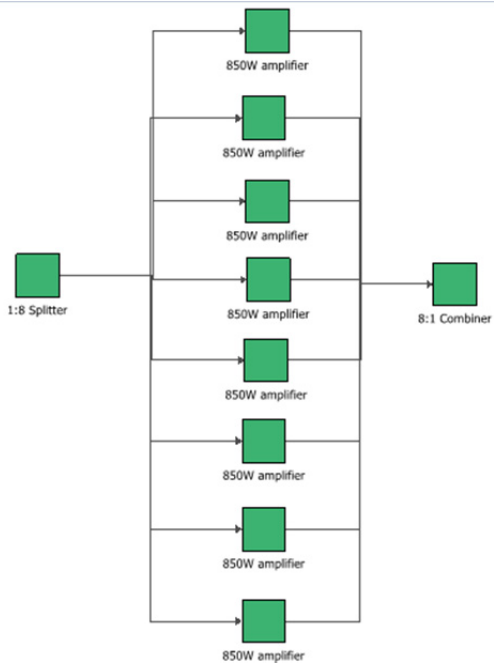

Figure 2: The pre-amplifier.

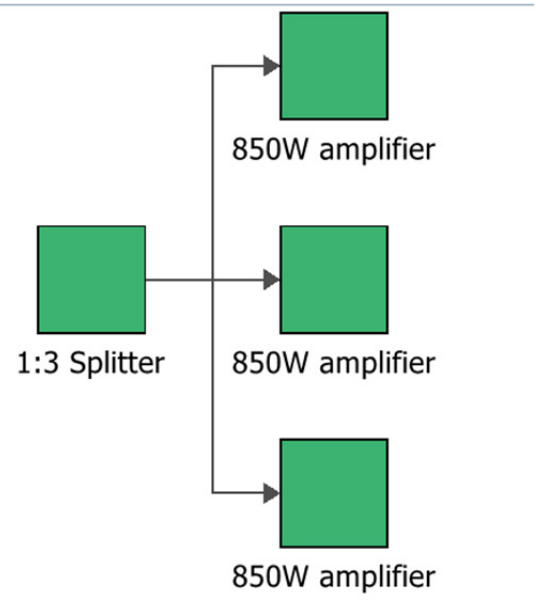

Figure 3: The main amplifier.

ISBN 978-3-95450-182-3

Table 1: MTBF of Every Component

Component	MTBF/h	Distribution of the failure rate	Data source
Limiter	$6* 10^5$	Exponential distribution	estimated
1:8 Splitter	$6* 10^5$	Exponential distribution	estimated
850W Amplifier	$2* 10^5$	Exponential distribution	[4]
8:1 Combiner	$6* 10^5$	Exponential distribution	estimated
1:2 Splitter	$6* 10^5$	Exponential distribution	estimated
1:4 Splitter	$6* 10^5$	Exponential distribution	estimated
1:3 Splitter	$6* 10^5$	Exponential distribution	estimated
20:1 Combiner	$6* 10^5$	Exponential distribution	estimated
2:1 Combiner	$6* 10^5$	Exponential distribution	estimated
Coupler	$4 * 10^5$	Exponential distribution	estimated
Flowmeter	$4* 10^5$	Exponential distribution	estimated
Pump	$4* 10^5$	Exponential distribution	estimated
Central control	$4* 10^5$	Exponential distribution	estimated
Limiter	$6* 10^5$	Exponential distribution	estimated

At present the number of the amplifier in 20 KW solid-state amplifiers of CIADS is not determined. This talk willgive the number of the main amplifier from reliability.

RBD MODEL OF THE 20KW SOLID-STATE AMPLIFIER

Component Definition

The component defines a minimum unit. The main components of 20 KW solid-state amplifiers include 850 W amplifiers, splitters, combiners, couplers, limiter, central control, flowmeter and pump.

850 W amplifiers contain LDMOS, circulator and power supply. Adjustable attenuator, RF switch and driven amplifier are included in the limiter. The central control is an industrial personal computer. Splitter, combiner and coupler are made of module individually. The amplifier has a flowmeter and a pump.

Hypotheses and Assumptions

Using assumptions are as follows:

1. All components have only two states: fault and running.
2. The fault density of components obeys exponential distribution. Every fault disables the component and it must be maintained.
3. There is no contact between components. The fault of one component can't cause non-function of other components.
4. The mean time between failure (MTBF)of 850 W amplifiers is constant below rated power.
5. The loss of power combination and error is not considered.

Reliability Data

The reliability data includes MTBF and the mean failure rate(λ). In the case of exponential distribution, the reciprocal of MTBF is λ . At present, much reliability information is estimated according the experience of running.

RBD Model

20 KW main amplifiers that at least need twenty-four 850 W-amplifiers output the power of 20 KW. the pre-amplifier and the main amplifier have relationship of parallel. Other components have relationship of series. The RBD model of 20 KW solid-state amplifiers is similar to the schematic. We use ReliaSoft to model RBD.

SIMULATION RESULTS

In the model the simulation time is two thousand hours that imply the running time of the solid-state amplifiers. The number of point results is ten. We use normal simulation and one seed. The simulation number is one hundred thousand. The pre-amplifier has three-paralell amplifiers. Reliability of different redundancy in the main amplifier is as followed (see Table 2):

Table 2: Relationship Between Reliability and Redundancy

REDUNDANCY	RELIABILITY
24/24	0.71043
24/25	0.90155
24/26	0.90232
24/27	0.90363
24/28	0.90335
24/29	0.9035
24/30	0.90316
24/31	0.90327
24/32	0.9031
24/33	0.90425
24/34	0.90394
24/35	0.90341
24/36	0.90313
24/37	0.90302
24/38	0.90276
24/39	0.90359
24/40	0.9039
24/41	0.90354
24/42	0.90392
24/43	0.90328
24/44	0.90366
24/45	0.90253
24/46	0.9017
24/47	0.90251
24/48	0.90467

SUMMARY

Reliability relative to the number of redundant amplifiers is similar to logarithm. 20 KW solid-state amplifiers that have 27 is optimal from reliability. And if there are more redundant amplifiers, the cost approximates linear growth.

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ISBN 978-3-95450-182-3